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ABSTRACT

This is a collection of 12 working papers dealing with instructional management systems (IMS). The papers are divided into three sections--systems definition, pedagogical studies, and hardware/software studies. IMS is generically defined as a set of procedures and mechanisms for gathering and processing pupil data and returning useful information to those persons responsible for some phase of pupil performance. This definition requires further consideration of its two components: (1) the communications system used for moving data through IMS and (2) the data-gathering techniques, processing requirements, output report generation, and audiences involved in the successful operation of IMS. The first component is discussed in the first section of the papers, the second component is dealt with in the remaining two sections. (Author/IRT)

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1972 SWRL WORKING PAPERS

COMPUTER-BASED SYSTEMS TO FACILITATE INSTRUCTIONAL DEVELOPMENT
Joseph F. Follettie and Frank Teplitzky, editors

DESIGN OF AN INSTRUCTIONAL MANAGEMENT SYSTEM
John F. McManus, editor

THE INTEGRATION OF CONTENT, TASK, AND SKILLS ANALYSIS TECHNIQUES IN INSTRUCTIONAL DESIGN
David W. Bessemer and Edward L. Smith, editors

PROTOTYPE TESTING IN INSTRUCTIONAL DEVELOPMENT
Fred C. Niedermeyer, editor

DESIGN OF AN INSTRUCTIONAL MANAGEMENT SYSTEM

Edited by John F. McManus

SWRL EDUCATIONAL RESEARCH AND DEVELOPMENT
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PREFACE

The documentation of large-scale development endeavors in education is a phenomenon with which the educational R&D community has had modest experience, since there has been little large-scale development to document. SWRL documentation experience confirms the applicability of Derek Price's conclusion regarding the literature of research and the literature of development.

> A scholarly publication is not a piece of information but an expression of the state of a scholar or a group of scholars of a particular time. We do not, contrary to superstition, publish a fact, a theory, or a finding, but some complex of these . . . . If the paper is an expression of a person or several persons working at the research front, we can tell something about the relations among the people from the papers themselves . . . . It seems that technologists differ markedly from both scientific and nonscientific scholars. They have a quite different scheme of social relationships, are differently motivated, and display different personality traits [Price, 1970, pp. 7-9].

> Clearly, the published paper is not, in general, the end product of a worker in a technological subject; he appears to be instead concerned chiefly with the production of an artifact or process. What then is the role of literature in technology? I suggest that for the most part it is produced as an epiphenomenon. It comes about because many technologists have had scientific training and know full well the code of behavior of the scientist in which publication is not merely right and proper, but a high duty and a behavior expected by peers and employers . . . . In general new technology will flow from old technology rather than from any interaction there might be between the analogous but separate structures of science and technology [Price, 1965, pp. 560-561].

SWRL experience has been that the course of a well-managed development effort produces considerable documentation but that a good deal of the substance of the information exceeds structures and strictures of journal publication. The journal article constitutes an available medium, but the laundering of the information required to use the medium often washes out the message.

SWRL has found it unproductive to treat information and documentation in the abstract as a "communication problem." A more useful approach is to consider operational means of making information pertinent to large-scale development in education conveniently available to interested audiences. This perspective directs attention to specifying interested audiences and devising communication compatible with their need-to-know characteristics. SWRL information architecture recognizes several audiences.

Staff involved in the development per se and the contract sponsor are two of the most immediate audiences addressed by SWRL documentation. Communication relevant to these audiences is handled by SWRL Technical Notes and Technical Memoranda that chronicle the course of SWRL R&D. These documents range in length from a few to a few hundred pages depending upon their nature. Some 200 of these Technical Notes and Technical Memoranda are issued during the course of a year--a stack several feet tall.

A third audience is the invisible colleges in which SWRL staff actively participate. Collegial exchange of selected Technical Notes and Technical Memoranda serve this audience adequately.

Another audience is product users. A volume of product working papers that brings together the documents associated with the development of each product is issued at the time the product is made available for general use and provides relevant information for this audience.

This leaves the general audience of students, scholars, and other members of the R&D community in education. SWRL Technical Reports and Professional Papers, largely accessed via the ERIC system, are directed to this broad audience. Journals, professional meetings, and other classical scientific and technical information exchange mechanisms are also used.

But each of these mechanisms involves a packing and rationalizing of information into independent pieces that inherently involves time delays and loses some of the original flavor of the work in the process. To reduce the time interval and retain the freshness of the work, an Annual Working Papers series has been initiated. The thematic topics that provide convenience categories for representing inquiry completed during the past year that is of timely interest to a sector of the educational R&D community will be identified. The documents relevant to these topics will then be organized into the volumes constituting

the Annual Working Papers for that year. "Design of an Instructional Management System" is one of four such volumes for the year 1972. The other three volumes of the 1972 SWRL Working Papers, available through the ERIC system, include the following titles:

The Integration of Content, Task, and Skills Analysis Techniques in Instructional Design (David W. Bessemer and Edward L. Smith, editors)

Prototype Testing in Instructional Development (Fred C. Niedermeyer, editor)

Computer-Based Systems to Facilitate Instructional Development (Joseph F. Follettie and Frank Teplitzky, editors)

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I. System Definition

Working Paper 1

THE SCOPE OF IMS VERSION 3 (TM 5-72-05)

John F. McManus

Generic Definition of IMS

IMS may be generically defined as a set of procedures and mechanisms for gathering and processing pupil data, and returning useful information to those persons responsible for some phase of pupil performance. This definition requires further consideration of its two components:

1. the communications system used for moving data through IMS; and
2. the data gathering techniques, processing requirements, output report generation, and audiences involved in the successful operation of IMS.

The first component may be bounded briefly within this section of the paper. Bounding the second requires consideration of the development history of IMS; this receives attention in the sections that follow.

A communications system (ComSys) may be defined as a set of mechanisms and procedures for inputting and storing data and returning information to appropriate audiences. While this definition may seem virtually the same as that of IMS, it should be recognized that a ComSys is a means by which data are moved and processed and does not delineate the data to be gathered or information to be provided. A ComSys comprises three basic components: input, data transmission to and from a processor, and output. Present research efforts center around the development and improvement of communications systems through the refinement of these three processes.

Three communication systems have been installed for the 1971-72 tryout. ComSys 1 involves U.S. Mail in - U.S. Mail out. ComSys 2, school mail in - school mail out. A major technological advancement is made with the installation of ComSys 3, which involves source data automation (SDA). ComSys 3 utilizes an on-site scanner for input and an on-site printer for output. This further automation greatly expands the information transmission potential without increasing the complexity of the human resources or the ad hoc information transmission contingencies for the school user.

IMS Versions 1 and 2

Version 1. SWRL's activity in computer-based instructional management can be traced back to 1965. Work with System Development Corporation (SDC) was instituted in 1966 to show the feasibility of computer managed instruction. Under subcontract for four years, SDC developed an operating instructional management system, first on the Q32 computer and later on the IBM 360/67. Researchers chose the state-adopted Ginn First Grade Reading Series as the vehicle of instructional management. During the summer of 1966, four teachers worked at SDC writing objectives and items to measure those objectives for that reading series. The tryout was conducted during school year 1966-67 in four classrooms. Data were gathered in the form of pupil responses on 8½ x 11 inch test sheets, were scanned by an IBM 1231 optical scanner, and the card output was transferred to tape for processing. Many output formats were generated by teachers, and participating school personnel were asked to assist in

the evaluation and redesign of the output formats. A similar tryout was conducted in 1967-68 in four more classrooms with the pupil performance measures being the source of input and the teacher the main recipient of output reports.

Work during 1968-69 centered around transferring the programs to a third generation computer, improving file maintenance and report generating capabilities, as well as initial efforts on computer-generated instruction in mathematics. Also, a study was prepared by Collins (1969) to evaluate three hardware levels of instructional management.

IMS Version 1 operates on an IBM 360/67 computer possessing certain required characteristics. IMS Version 1 is available but not recommended for school use.

Version 2. During the 1969-70 school year, SWRL operated a second version of IMS. Teachers in 80 classrooms were asked to administer Criterion Exercises for the First Year Communication Skills Program (FYCSP), to score the exercises and to mark the outcome scores on class lists preprinted on machine-scannable forms. To initialize the process, SWRL gathered pupil names from all participating teachers, keypunched the names according to district, school, teacher, and class, stored the information on computer tape and generated a class roster for every teacher and each unit on machine-scannable forms. These forms were mailed to the teacher, who was requested to record four marks, one mark for total score on each outcome of each Criterion Exercise, for every pupil in her class taking the Criterion Exercise. The sheets were mailed to SWRL for scoring on a service center Univac 1108 computer.

Test scores were generated, evaluated and reported by the SWRL Product Integration Division. This study demonstrated the ability of SWRL to prepare, with precision, scannable answer sheets, to train teachers how to mark answer sheets, and to read teacher-marked sheets with reliability. A final report of that study is presented by Hanson (TM 5-70-01) and Hanson et al. (TM 5-70-03).

Boundaries of IMS Version 3

IMS Version 3 may be bounded in terms of the following parameters:

- pedagogical-engineering interface
- hardware configuration
- scope of instructional systems and/or curricular programs to be managed
- system exercise

Version 3 Pedagogy-Engineering Interface

The development of IMS Version 3 was initialized by setting forth four functions:

1. Current performance status reporting
2. File maintenance and updating
3. Diagnosis and prescription
4. Computer-generated instruction

The intent of these functions was to provide an interface between an engineering perspective of IMS and a pedagogical perspective of IMS. This interface objective demanded the integration of pedagogical and

engineering referents. Although the four functions as set forth did capably fulfill the initializing intent, as development proceeded it became patently clear that the communication base was underdefining both the scope of the version and its development operations.

The problem arises because the logic for each function as well as each of the functions itself is independent. Thus, the functions tended to be either over-interpreted, with surplus expectation the consequent, or under-interpreted, with shallow exploitation the consequent. This unfortunate condition was most evident in confusion concerning Function 1 and Function 3. The "fine print" made it clear that much information commonly termed diagnostic and prescriptive would be drawn from current performance data. This stipulation was usually overlooked, and "scores only" were assumed. Likewise, it was stipulated that Function 3 would involve algorithmic data messaging rather than simple table lookups. This stipulation also was commonly disregarded.

In sum, while the four functions set forth were useful to bound development initiation, it is clear that a better base for development completion can be set forth in terms of a pedagogy-information interface.

Pedagogy-Information Interface

Version 3 completion will provide the capability to present users with a variety of information options. These options are bounded by the following considerations:

. selection of data to be gathered

. selection and/or preparation of data gathering devices and procedures

. aggregation of data to comprise output information

. identification of audiences to receive output reports

. preparation of output formats and determination of periodicity of information reporting.

Each of these components has been analyzed and many preliminary decisions have been made. The data comprise pupil performance measures taken at a determined number of times (usually 10 or 15) in the instructional program. These measures are gathered on machine readable answer sheets. Several types of data aggregation have been programmed. The most basic is the listing of pupils by group or class, their scores on various outcomes within the test, and class and group averages by outcomes. In addition to current test results, other types of reports have been proposed: grouping suggestions, pacing projections, and suggestions for supplementary instruction.

Several audiences have been identified as central for reception of output reports. Most important are teachers, principals, curriculum supervisors, district level personnel, and parents. SWRL researchers must be considered, as well as pupils themselves. Efforts are being made to measure the impact of output formats on various audiences as well as the importance of the frequency (periodicity) of report generation.

Hardware/Software Development Configuration

The IMS hardware configuration is documented in IMS Version 3 Preliminary Planning Documentation (SWRL, 1971). Input devices for ComSys 3 include an on-site optical scanner and high-speed keyboard. A data concentrator unit (DCU) receives input from school sites, pre-processes the data received, and transmits them over telephone lines to a large central processor which contains the resident IMS software. Files are updated and reports are generated and returned to the DCU, which transmits the output to a high-speed character printer at the school location.

The completion of Version 3 will require alternative configuration trade-off analyses that are currently in progress.

Instructional Systems

It was decided to use one instructional system for Version 3 operation, the SWRL First Year Communication Skills Program (FYCSP). However, any instructional system containing certain characteristics, i.e., a bounded subject matter, operationally defined objectives, measures of learning performance, and procedures for removing identified learning deficiencies can be handled by IMS. The SWRL Learning Mastery System (LMS), which contains procedures for a teacher-operated management system, possesses the required characteristics for use in IMS. Thus, LMS Harper and Row 1, 2, and 3 as well as LMS Macmillan Bank Street First Year Reading are included in the tryout for school year 1971-72.

System Exercise

To check out and evaluate the operation of IMS in a natural school setting, Version 3 was installed in several cooperating school districts in school year 1971-72. There are five basic parts to this tryout exercise: 1) materials preparation, 2) training, 3) installation, 4) monitoring of operation, and 5) evaluation.

Materials preparation. This involved adaptation of certain materials within the instructional systems selected for use in IMS. In most cases these were modified to be machine readable. Considerations of ease of pupil use and cost of production were influential in design of forms. The adapted materials were pretested in several classrooms to assess Kindergarten pupils' ability to mark machine readable forms. The study is reported by McManus (TN 5-72-04). Analytic work in design of assessment devices for the LMS and FYCS programs is reported in TN 5-72-04.

Training. Materials and procedures were prepared to train teachers and pupils for participation in IMS. Directions for administering Criterion Exercises were prepared. All school personnel were trained by IMS and DRS staff. A report on this aspect of IMS has been prepared by Gibbs (TN 5-72-20).

Installation. The installation of IMS is considered terminated with the completion of training on a given communication system (ComSys) for inputting, processing and receipt of information on pupil performance. Again materials and procedures were developed. Clerks, teachers, administrators and district personnel were trained.

Monitoring of operation. To assure successful IMS operation through efficient use of the ComSys, SWRL researchers monitor the input, processing, and output flow, modify procedures where required, and contact individuals to correct observed malfunctions in the systems. Cooperating school personnel are also encouraged to call SWRL to clear up difficulties and to make suggestions for smoother operation.

Evaluation. Data are gathered to measure the effectiveness of ComSys operation. This information serves to make enroute changes as well as to suggest major revisions for subsequent IMS versions or later installations of the same version.

IMS Version 3 Status

The scope of the 1971-72 tryout is depicted in Table 1. Shown are the instructional systems, the communications systems and the number of classes involved in each cell, together with cross totals. The number of pupils, listed under class in parentheses, is estimated by multiplying class number by 22, the average number of pupils per participating class. Approximately 1900 pupils in 86 classes are involved in this tryout.

Table 2 shows the number of schools participating in the tryout by ComSys and programs within ComSys.

Initial monitoring data indicate that errors in teacher operations of the system are minimal, especially after correction of "first-time" errors by means of personal conversation with teachers. Pupil marking of FYCSP sheets is of acceptable quality and consistency. Teacher affect appears high and cooperation of district-level personnel and school administration is encouraging.

Table 1

Total N for Class and Pupil by ComSys and Instructional System for IMS Version 3 Installation, 1971-72

Instructional System	Communication System I	II	III	Total
FYCSP	3 (66)	14 (308)	4 (88)	21 (462)
HR-1	12 (264)	9 (198)	3 (66)	24 (528)
HR-2	10 (220)	4 (88)	2 (44)	16 (352)
HR-3	5 (110)	6 (132)	5 (110)	16 (352)
Macmillan	0 (0)	4 (88)	5 (110)	9 (198)
Total	30 (660)	37 (814)	19 (418)	86 (1892)

Note: Pupil N in parentheses is derived by multiplying class N by 22, the average number of pupils per class.

Table 2

Number of Schools Participating in IMS Tryout
by ComSys and Program within ComSys

	ComSys			
	I	II	III	Total
Total Number of Schools	5	9	1	15

	ComSys			
	I	II	III	
Number of Schools by Program				
FYCSP	1	7	1	9
HR-1	3	5	1	9
HR-2	4	3	1	8
HR-3	3	3	1	7
MBS	0	3	1	4
	11	21	5	

Note: Column and row totals do not equal 15, since some schools are participating in more than one program within ComSys.

Completion of Version 3

IMS Version 3 will be complete when work has been finished on defined elements of the five bounded sets identified earlier and treated in turn below.

Data to be Gathered. Input from one instructional system, in the form of assessment data, will meet requirements for this bounded set. These requirements are presently met. The SWRL Kindergarten Program and the SWRL Learning Mastery Systems satisfy the minimal requirement.

Devices and Procedures. The development and installation of one commercializable communications system with its concomitant processing capability will meet this requirement. Commercializability is defined as the willingness of a large educational market to pay for defined services. This in turn requires purveyor producibility and user manageability.

Aggregation of Data. Performance measures will be aggregated by individual, group, class, school, district, and possibly by area and state.

Audiences. Four generic commercial audiences will receive reports: instructors, supervisors, administrators, and parents. Optional alternatives will include students and researchers.

Output Formats and Periodicity. A compendium of output formats will be prepared, with options designed for each of the four user groups. The frequency of report availability may differ by groups, but each output report will utilize pupil performance information on each unit Criterion Exercise.

Target Date for Completion

Requirements for Version 3 will be met by June 1973, with the completion of the 1972-73 system exercise.

REFERENCE

Collins, Thomas F. "A Study of Computer Configurations for Instructional Management Systems," Technical Memorandum-4508, System Development Corporation, 1970.

Working Paper 2

OVERVIEW OF THE IMS VERSION 3 COMPUTER SOFTWARE CONSIDERATIONS IN THE 1971-72 SYSTEM EXERCISE (TN 5-72-45)

Howard Wolfe

During the 1971-72 academic year, SWRL staff implemented and operated a research based, computer operated IMS system [1].* The configuration consisted of:

1. a Data Concentrator Unit (DCU) whose main components include a PDP8 mini-computer, with 8000 words of memory, 3 magnetic tape drives, disk storage, telecommunication interface component, and a low to medium speed card reader and line printer.

2. a large central IBM 360/91 computer located at UCLA.

The specific functions of the system elements and their interrelationships are depicted in section 9.0 below. The remaining sections of the document are presented in outline form to highlight the system features and to reference relevant documentation.

1.0 - FUNCTIONS

A. Pupil Performance Reporting
The Pupil Performance Report processing consists of:
1) Data Collection
   a) criterion exercises
   b) Class Record additions and deletions
2) Scoring the pupil responses made on the criterion exercises
3) Updating the Pupil Data Base with,
   a) the outcome scores, total score, item responses and test date of each criterion exercise processed
   b) the Class Record additions and deletions
4) Monitoring the data collected as follows:
   a) procedural errors on the part of the teacher are noted in the Processing Conditions Report
   b) system errors are listed in the Central Computer IMS Processing System (CIMS) Run Log
5) Producing a Class Record Report which notes class roster changes
6) Producing a Pupil Performance Report by class and criterion exercise unit number
7) Returning the reports in 4a, 5, and 6 to the teacher
8) Returning the CIMS Run Log in 4b above to SWRL for analysis

*Bracketed numerals reference documents listed at the back of this paper.

B. Pupil Data Base Maintenance
This processing is as follows:

1) Data Collection
   a) Teacher requests for Pupil Data Base changes, e.g., correcting a misspelled name.
   b) Class Records
2) Updating the Pupil Data Base with the information received in step 1
3) Listing the changes made to the Pupil Data Base in the Pupil Data Base Maintenance Run Log
4) Listing the new Pupil Data Base

A step by step description of the Pupil Performance Report procedure is found in Section 7.0. The flowchart on which the description is based is in Section 9.0. The Student Data Base Maintenance procedure is similarly described in Sections 8.0 and 10.0. Section 2.0 through 5.0 describe the components that make up the two procedures.

2.0 - IMS COMMUNICATION SYSTEMS

A. INPUT/OUTPUT MODES [2, 3]
Table 1 indicates the three communication systems implemented in the 1971-72 tryout.

TABLE 1

OUTPUT MODE \ INPUT MODE	U.S. MAIL	COURIER	REMOTE SCANNER	REMOTE TELETYPE
U.S. MAIL	COMSYS 1			
COURIER		COMSYS 2		
REMOTE TELETYPE			COMSYS 3	COMSYS 3

In COMSYS 3, Class Record Update information is transmitted to the 690 using an on-line teletype located in a participating school district. All other COMSYS 3 information is coded on scanner sheets and transmitted to the 690 by the on-site scanner.

B. INPUT/OUTPUT DEVICES

Table 2 indicates the Input/Output devices used in the three

COMSYS modes. In COMSYS 3 the DCT-500 and Xerox Scanner/ Copier share a 103A2 data set. SWRL has a matching 103A2 data set that is interfaced with the 690 by using a PT08 Data Set Adapter.

TABLE 2

	INPUT		OUTPUT	
	TELEPRINTER	SCANNER	TELEPRINTER	PRINTER
COMSYS 1	---	OPSCAN 100	---	MOHAWK LINE PRINTER
COMSYS 2	---	OPSCAN 100	---	MOHAWK LINE PRINTER
COMSYS 3	DCT-500	XEROX SCANNER/ COPIER	DCT-500	---

C. IMPLEMENTATION OF INSTRUCTION PROGRAMS

Five programs; First Year Communication Skills (FYCSP), Harper & Row-1 (H&R-1), Harper & Row-2 (H&R-2), MacMillian Bank Street (MBS) and Harper & Row (H&R-3) were implemented in COMSYS 1 & 2. All but H&R-3 also used the COMSYS 3 mode of data transmission.

3.0 - SOURCE INPUT DOCUMENTS

A list of the types of source input documents together with the entry modes and purpose of the form is found in Table 3. Note that the scanner sheet design is specific to the scanner.

TABLE 3

FORM TYPE	ENTRY MODE	FUNCTION
IMS Class Record Sheet [2, 3]	Cardreader	Insert Class Record into the Pupil Data Base.
Teacher Note (by mail or telephone)	Cardreader	Change particular record(s) in Pupil Data Base.

IMS Class Identification Sheet/Update Sheet [2, 3]	A) XEROX Scanner (COMSYS 3) B) OPSCAN 100 Scanner (COMSYS 1&2)	The sheet contains the date of test and the class to which all following sheets until the next identification sheet belong. In COMSYS 1&2 the Class Identification Sheet can be used to add a pupil to the class record, by marking the "Add a Pupil Box" on the sheet. If the "Add" feature is being used the pupil's name and group number are also indicated.
Criterion Exercise Response Sheet (FYCSP + HR-3) [2, 3]	A) XEROX Scanner (COMSYS 3) B) OPSCAN 100 Scanner (COMSYS 1&2)	Contains pupil marked item responses on Criterion Exercises. Additionally a "delete" box can be marked by the teacher to delete the pupil from the Class Record. HR-3 was not implemented in COMSYS 3.
Criterion Exercise Reponse (or Record) Sheets (HR-1, HR-2, MBS) [2, 3]	A) XEROX Scanner (COMSYS 3) B) OPSCAN 100 Scanner (COMSYS 1&2)	Contains the teacher marked items according to the responses made by the pupils the teacher has tested. (10 pupils/page) Additionally, "delete" boxes exist for each pupil so that the teacher can indicate which pupils should be removed from the Class Record.
IMS Update Form [3]	DCT-500 (COMSYS 3)	Contains the class id, name and group number of pupil to be added to the Class Record.
End of Class Sheet	XEROX Scanner (COMSYS 3)	Defines the end of class input.
End of Transmission [4]	XEROX Scanner (COMSYS 3)	Signifies that all data has been transmitted.

4.0 - OUTPUT DOCUMENTS

Table 4 contains a list of the printed documents created during IMS processing.

TABLE 4

Output Documents

TITLE	PURPOSE
Pupil Performance Report [5]	Displays pupil percentage scores by outcome. This report is produced by CIMS.
Processing Conditions Report [5]	Notes teacher procedural problems. This report is produced by CIMS.
Class Record Report [5]	Indicates the addition or deletion of pupils to a Class Record. This report is produced by CIMS.
Data Input Tape List	Used to maintain a record of the translated source data each time OPSN (COMSYS 1&2) or RIMS (COMSYS 3) is run.
Data Input Tape Summary [6] or Console Listing [9]	Each time RIMS accepts a class id sheet it is printed on the console listing. OPSN puts similar output to the 690 printer but includes an error check of the id fields and a count of the number of sheets processed per class.
CIMS Run Log [5]	Maintains system accounting data of CIMS program run.
Maintenaince Program Log [7]	Shows changes made in the Pupil Data Base by the Student Data Base Maintenance program.
Pupil Data Base List [7]	Maintains a record of the Pupil Data Base. It is produced each time the Student Data Base Maintenaince program is used.

5.0 - IMS COMPUTER PROGRAMS

These programs are of two types: Those that operate on the 690DCU, handling and pre-processing scanned input data; and those that reside in the Central Computer and perform IMS oriented functions.

A. OPSN [8, 9]
This program operates in the 690DCU and prepares COMSYS 1&2 mode inputs in the following way:

1. Reads the OPSCAN 100 Scan Tape
2. Edits and formats each Scan Tape Record for transmission to the Central Computer. This is done according to table information keyed from the program and criterion exercise unit code fields on each Scan Tape Record.
3. Writes the reformatted record to the Data Input Tape. Port number 10 (in first two entries of the reformatted record) is assigned to the Data Input Tape records created by OPSN
4. Prints a summary of the Scan Tape data processed.

B. RIMS [6]

COMSYS 3 mode input data from an on-site XEROX Scanner is received by the 690 DCU program RIMS. RIMS does the following:

1. Receives data on-line from a teleprinter and scanner at a on-site school location. RIMS can process multiple on-site sources with apparent simultaneity.
2. Checks the input for parity and record length. Records which have not been transmitted correctly are rejected and must be resubmitted.
3. Translates scan data.
4. Allows teletype user to edit a line of data before entering that line for IMS processing.
5. Writes the received records to the Data Input Tape. The first two digits of each record contain the port number (0-9), through which the record was received by the 690.
6. Creates a console listing of the class identification sheets processed.

C. RJS [10, 11]

This 690 software provides Remote Job Service to the Campus Computer Network at UCLA. The main function of RJS with respect to IMS are:

1. Transmitting the Data Input Tape to the 360/91 at UCLA for CIMS processing.
2. Receiving the reports generated by CIMS for delayed transmission to either the 690 printer or a remote site teletypewriter.

D. CIMS [5]

This 360/91 program performs the following functions:

1. Sorts the Data Input file on class identification, criterion exercise, pupil, and page (or list) codes.
2. Scores the item response data.
3. Saves the outcome scores, total scores, item responses, and test dates in the Pupil Data Base.

4. Updates the Class Records in the Pupil Data Base to reflect pupil additions and deletion.
5. Generates the Pupil Performance, Processing Conditions and Class Record Reports together with edit command records which:
   a) indicate the site to which the 690 is to transmit the reports.
   b) control the number of blank lines to be inserted into the report text by the 690.

E. SIMS [12]

The purpose of this 690 program is to transmit each report in the Report File according to the edit commands embedded in the file. Up to three terminals can be service concurrently by SIMS. The line printer can be designated as a fourth output device. Although designed for COMSYS 3 SIMS is used for COMSYS 1 & 2 by directing the output to the line printer.

F. STUDENT DATA BASE MAINTENANCE [7, 13]

This 360/91 program is used to:
1. Add Class Records to the Pupil Data Base
2. Delete records in the Pupil Data Base
3. Insert records in the Pupil Data Base

G. TEST DESCRIPTOR LOADER [14]

LOADER creates a disk file containing the information needed to score the criterion exercises. LOADER reads in the test scoring data from punched input and creates one disk record for each criterion exercise. The records are in sequence by program and criterion exercise code. Retrieval of these records is described in 6 C.

H. LABL/LABS [15]

690 utility programs which read names and addresses from punched cards and print multiple copies for addressing and other labeling purposes.

6.0 - IMS FILES

A. SCAN TAPE [8, 9, 16]

The OPSCAN 100 reads mark sense sheets and writes the data of each sheet read to magnetic tape (1 record/sheet). On each sheet one character is transmitted to tape for each field

defined by the Q & K OPSCAN 100 control sheets which precede each set of scanner sheets of a given format. The string of characters produced is in a left to right, top to bottom of scanner sheet sequence. All the OPSCAN 100 sheets mentioned in Table 3, Section 3.0 are so processed.

B. DATA INPUT FILE [5]

This file can be created by either the OPSN program (COMSYS 1&2) or the RIMS program (COMSYS 3). The Data Input File contains the content of the XEROX (COMSYS 3) or OPSCAN 100 (COMSYS 1&2) scanner sheets translated to a common format. This format simplifies further processing of this file.

C. TEST DESCRIPTOR FILE [17]

This file is stored on drum or other direct access device. Each record in the file pertains to a given criterion exercise and contains the answer key and outcome of each item on the test. Each record can be located by a calculation based on its criterion exercise and instructional program code. The Test Descriptor File is created using the Test Descriptor LOADER Program.

D. PUPIL DATA BASE [5]

The Pupil Data Base (PDB) is maintained on magnetic tape. It is updated each time a Pupil Performance or Pupil Data Base Maintenance run is made. Updating consists of merging the old PDB with the performance, class record, or maintenance data to create a new PDB tape.

The Pupil Data Base (PDB) is structured by class. Each class contains one type 1 record, one type 2 record, one type 3 record/pupil, one type 4 record/pupil's criterion exercise, and one type 5 record. All records in the PDB are sequenced by class identification code and record type . Type 3 records are further sequenced by pupil code. Type 4 records are further sequenced by criterion exercise unit and pupil codes.

The type 1 and 2 records contain the site, district, school, teacher, program, grade, and class identification names and codes. Each type 3 record contains a pupil's name, code, status, and current group number. Each type 4 record contains a pupil's criterion exercise outcome scores, total score, item responses, test dates, unit code, and group number (at the time of test). The type 5 record indicates the end of the class.

E. SORTED DATA INPUT FILE [5]

To merge the Data Input File data with the old Pupil Data Base, CIMS sorts the Data Input File on Class Identification, criterion exercise unit, pupil and page (or list) codes to create the Sorted Data Input File.

F. REPORT FILE [5]

This file contains the reports generated by CIMS, namely, the Pupil Performance, Processing Conditions, and Class Record reports. The reports are in "print" image except for records which control the site destinations and line spacing.

7.0 - PUPIL PERFORMANCE REPORTING PROCEDURE

Step 1 (This procedure refers to the flowchart in Section 9.0)

A) (COMSYS 1)	Teacher mails OPSCAN Criterion Exercise and Class Record Changes sheets to SWRL. Next step in 2A.
B) (COMSYS 2)	Same as A) but using courier service. Next step is 2A.
C) (COMSYS 3)	Operator keys data on IMS update forms using a teleprinter on-line to SWRL's 690 DCU. Next step is 3B.
D) (COMSYS 3)	Operator uses XEROX 660 Scanner/Copier to transmit XEROX class identification and test sheets on-line to SWRL's 690 DCU. Next step is 3B.

Step 2

A) (COMSYS 1&2)	OPSCAN sheets are received by SWRL, pre-processed and run through the OPSCAN 100 scanner which creates the SCAN DATA file on magnetic tape. Next step is 3A.

Step 3

A) (COMSYS 1&2)	The 690 OPSN program edits the SCAN DATA file and creates the DATA INPUT file on magnetic tape. A summary which notes the number of sheets processed per class and coding errors is printed. Next step is 4.

B) (COMSYS 3)

The 690 RIMS program receives the teleprinter entries (STEP 1C) and scanner data (STEP 1D) and creates the DATA INPUT file. Next step is 4.

Step 4

(COMSYS 1, 2, 3)

The 690 utility program (MLST) lists the DATA INPUT file for record purposes. Next step is 5.

Step 5 & 6

(COMSYS 1, 2, 3)

The DATA INPUT file is transmitted to UCLA using Remote Job Service (RJS) software. The effect of this is to insert the DATA INPUT file into the system "card input" file.

Step 7

(COMSYS 1, 2, 3)

The 360/91 program CIMS program sorts the DATA INPUT FILE (SDIF). In turn, the SDIF is processed and the print images except for the 690 edit commands, of the Pupil Performance, Class Record, and Processing Conditions reports are obtained. The Pupil Data Base is updated with the item responses, outcome scores, total scores, test dates, and class record changes. Scoring of criterion exercise is done using test descriptor information read in from the Test Descriptor File. The print image of the CIMS Run Log is generated. Next step is 8.

Step 8 & 9

(COMSYS 1, 2, 3)

The reports and run log generated at the 360/91 are transmitted to SWRL using RJS. The 690 RJS software puts the CIMS RUNS LOG to the 690 printer while the reports are output to the REPORT file. Next step is 10A for COMSYS 1&2, and 10B for COMSYS 3.

Step 10

A) (COMSYS 1&2) — The 690 SIMS program directs all COMSYS 1&2 reports to the 690 printer. Next step is 11A (COMSYS 1) or 11B(COMSYS 2).

B) (COMSYS 3) — The 690 SIMS program directs the remote site information to the appropriate teleprinter. Next step is 12.

Step 11

A) (COMSYS 1) — The reports are mailed to the school sites. Address labels are printed using 690 utilities LABL and LABS. Next step is 13.

B) (COMSYS 2) — The reports are delivered to the schools by courier. Address labels are printed using 690 utilities LABL and LABS. Next step is 13.

Step 12

(COMSYS 3) — The reports are printed on the remote teleprinter. Next step is 13.

Step 13

(COMSYS 1, 2, 3) — The reports are distributed to the teachers.

8.0 - MAINTENANCE OF PUPIL DATA BASE

(This procedure refers to the flowchart in Section 10.0)

Step 1

A) — Teacher mails or telephones request to make a change in Pupil Data Base, e.g., a pupil's name is misspelled.

B) — Teacher mails her Class Record to SWRL.

Step 2 — Keypunch changes and Class Records.

Steps 3 & 4 — Changes/Class Record data are submitted using Remote Job Service (RJS) software to the 360/91 for processing.

Step 5 — MAINTENANCE program inserts into and deletes from the Pupil Data Base according

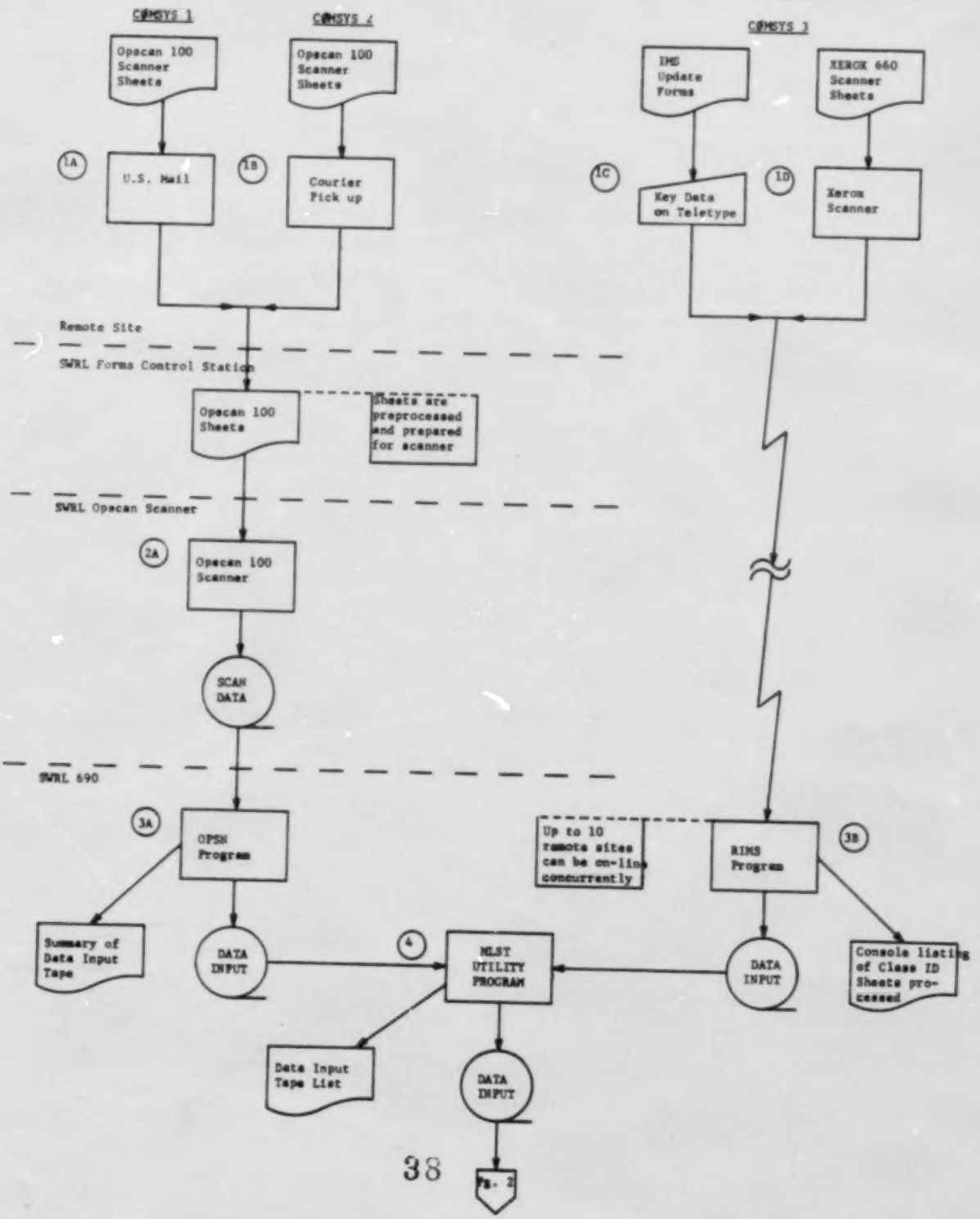
to the Changes/Class Records cards and creates a new Pupil Data Base. A Run Log of the changes made is printed together with a listing of the new Pupil Data Base.

Steps 6 & 7

RJS transmits the RUN LOG and list of new Pupil Data Base to SWRL where these are output on the 690 printer.

FLOWCHART LAYOUT FORM

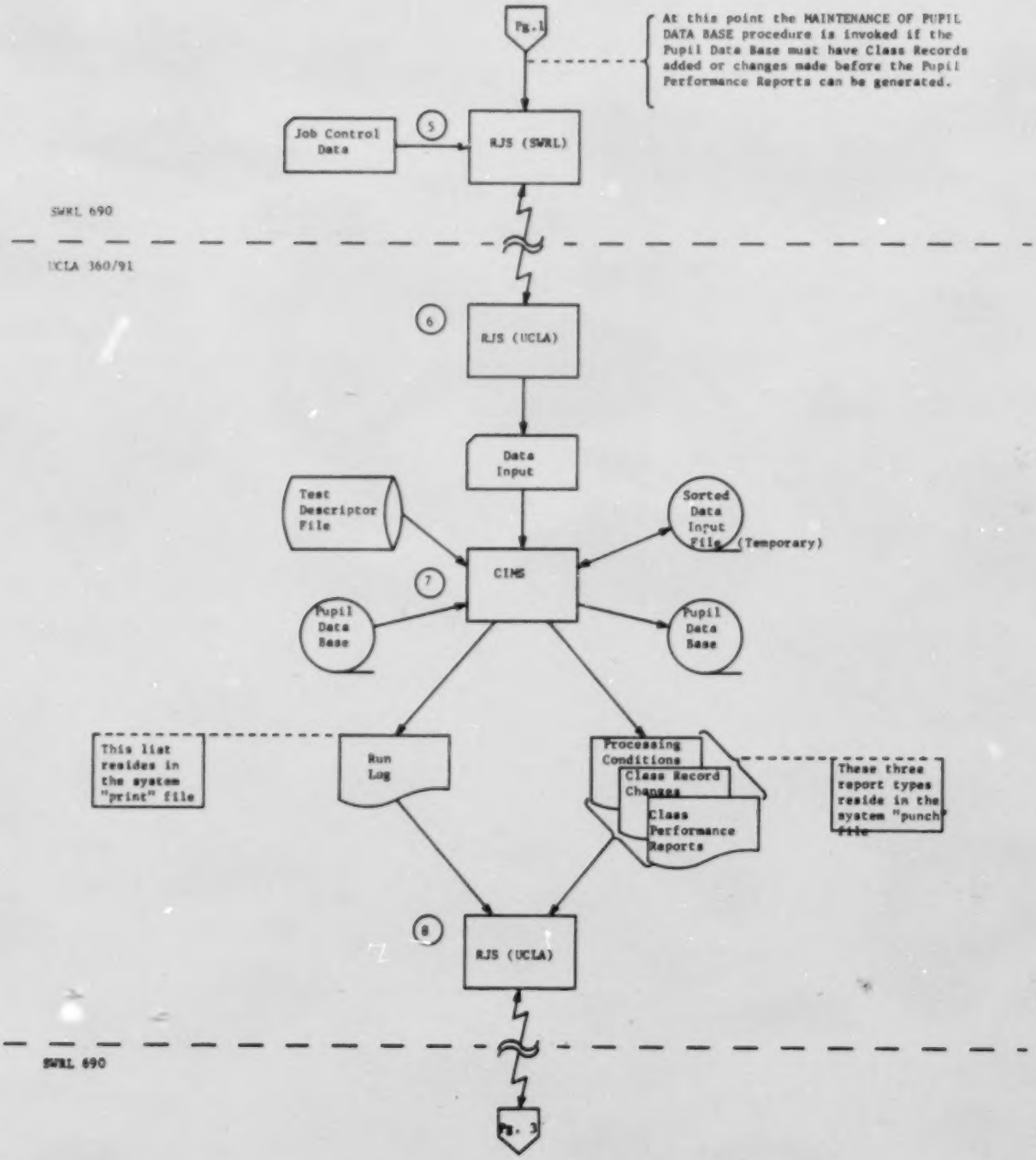
PROGRAMMER: Howard Wolfe DATE: 7-20-72
PROGRAM ID: IMS System Flow PAGE 1 OF 1



SWRL

Flowchart Layout Form

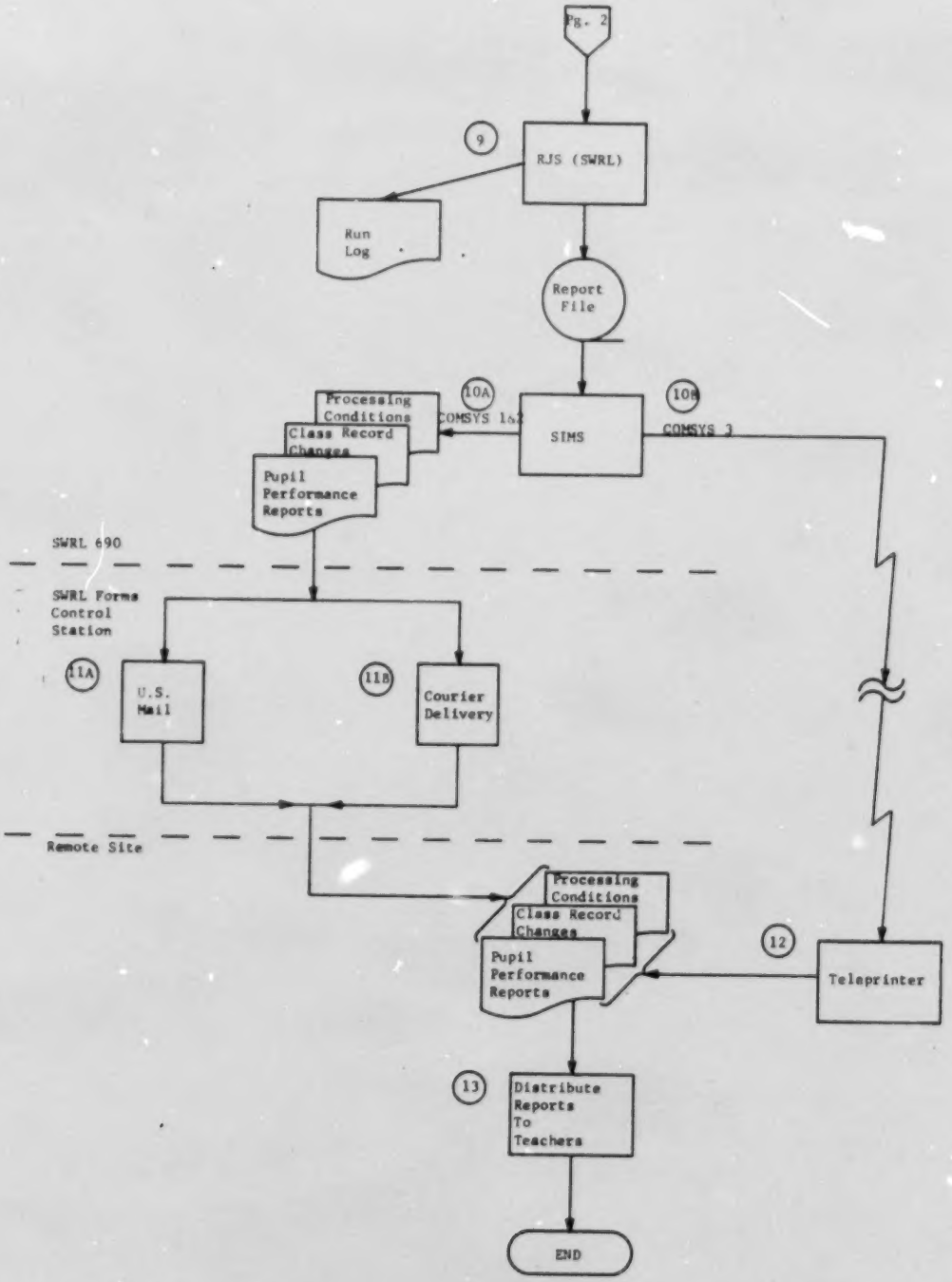
Programmer: Howard Wolfe
Program ID: IMS System Flow
Date: 7-20-72
Page 2 of 3



SWRL

Flowchart Layout Form

PROGRAMMER: Howard Wolfe
PROGRAM ID: IMS System Flow
DATE: 7-20-72
PAGE 3 OF 3



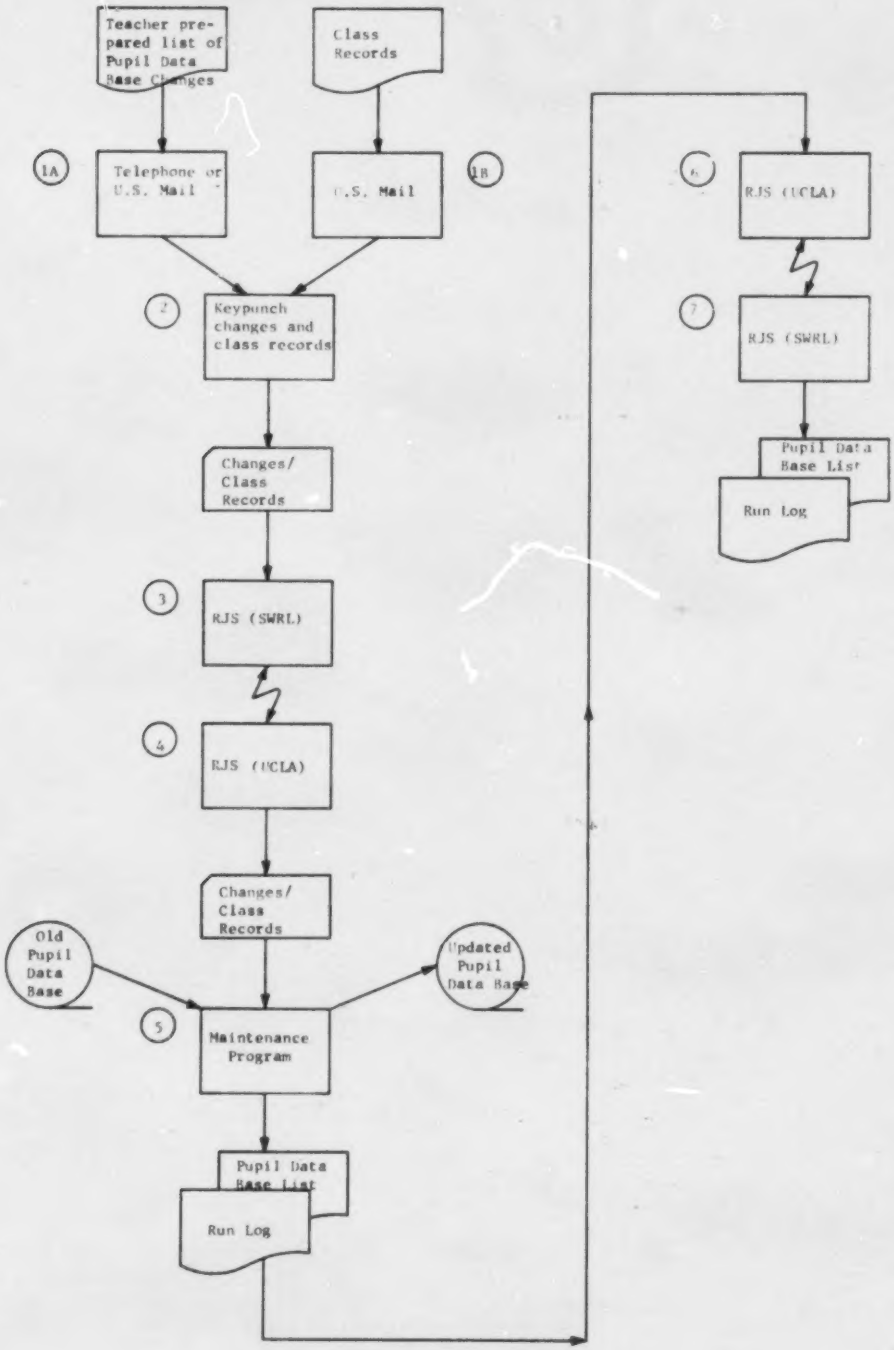
10.0 - MAINTENANCE OF PUPIL DATA BASE

SWRL

FLOWCHART LAYOUT FORM

PROGRAMMER: Howard Wolfe DATE: 4-20-72

PROGRAM ID: MAINTENANCE OF PUPIL DATA BASE PAGE 1 OF 1



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II. Pedagogical Studies

Working Paper 3

PRELIMINARY TRYOUT OF OPTICALLY SCANNABLE FYCSP CRITERION EXERCISES (TN 5-72-04)

John F. McManus

Little attention has been paid to the ability of kindergarten children to use optically scannable response sheets in an instructional management setting. Pupils participating in the SWRL FYCSP presently use a one-sheet, four-page set of multiple choice items, selecting their answer by placing an "X" in the box under the appropriate answer. A machine readable Criterion Exercise is necessary to permit source data automation of an instructional management system.

Therefore, three response formats were designed for pre-IMS-installation tryout. The forms contained ten responses per side, three response choices per item, a picture for each numbered response, and a page number. Additional features included precoding of program name, unit number, and page number, as well as space for a binary pupil code. Thus, while the content is the same as the FYCSP Criterion Exercise, the three forms differ in appearance, the main difference being ten items per side versus five.

Two schools, a total of five kindergarten classes, in the Los Angeles City Schools, were selected for work in the tryout. While the purpose of the tryout was manifold, a basic intention was to determine if pupils below grade one can properly fill in a optically scannable Criterion Exercise form. Psychometric literature suggests that grade three is the minimal lowest grade level to introduce these

forms, but the IMS situation is sufficiently different that feasibility at the kindergarten level was felt to be an attainable objective.

Background and Related Literature

Gaffney and Maguire (1971) conclude that pupils in grades four and five can handle separate mark-sense response sheets when provided with specific directions and practice. Pupils above fifth grade were able to make valid responses regardless of type of instruction. Second and third grade pupils were unable to use separate answer sheets with success. All pupils involved, i.e., grades two through eight, were able to answer questions effectively when using a test booklet that was not machine scorable. Cashen and Ramseyer (1969) also tested pupil ability to use separate answer sheets in virtually the same manner as the above study. Results indicate that third grade pupils above average ability used the sheets effectively. McKee (1967), although presenting no empirical data, conclude that third grade pupils "seemed to" be able to use a separate answer sheet.

Culhane and Stodola (1967) administered opinion questions to pupils in grades one through eight and found that all were able to respond on mark-sense IBM cards, even though many of the marks were too light to be read by machine. The dependent variable in this study was the number of marks the machine could read in a designated field, while in the first two studies, correct responses on a parallel form test were the criterion. Hieronymous (1961), working with third graders, found no significant difference among three training methods. However, all pupils were able to use separate answer sheets effectively.

From these studies it was concluded that:

1. Separate answer sheets can be used on achievement tests with third grade pupils;
2. Training pupils on the use of separate sheets appears important, but no one method has been shown to be significantly more effective than others;
3. Mark-sense cards were used as early as first grade to gather data on an opinion questionnaire;
4. No work with kindergarten pupils on scannable answer sheets has been reported.

Statement of the Problem

It becomes obvious that the facility of kindergarten pupils in handling scannable response sheets is an empirical question. The problem to be resolved is presented in four parts:

1. Can kindergarten pupils respond to oral questions on a mark-sense Criterion Exercise?
2. How does form design affect pupil marking behavior?
3. What training materials and procedures elicit appropriate pupil response?
4. How effectively does the SWRL optical scanner read kindergarten pupil response sheets?

The problem of quality control on SWRL production of Criterion Exercises has been resolved by Gibbs and Hooper (TN 5-72-05). It was determined that Production Services could produce forms with print tolerances, paper stock specifications, and ink characteristics that would

meet requirements set forth by the Optical Scanning Corporation. What remained to be answered was the question of grade level, forms design, and training appropriate for development and use of machine readable Criterion Exercises.

Procedures

A. Materials

Criterion Exercises for FYCSP Unit 1 were generated. The tests comprised one sheet, two sides, ten items per side, with a picture as well as a number for each item to assist pupils in identifying the proper response row. Three distractors per item were presented, with a response box below each option. Pupils were instructed to fill in the box under the correct response, making sure that the mark was dark and shiny. (Regular FYCSP directions instruct pupils to place an "X" in the appropriate box.) Three different shapes of boxes were used: vertical, horizontal, and square. The exercises were alike in all other aspects.

Characteristics of tryout materials and regular Criterion Exercises are compared in Figure 1.

B. Population

Seventy-six pupils from five kindergarten classes in two schools were involved. The age range was approximately four-and-one-half years to six years. SWRL requested that all pupils involved be using FYCSP. However, at least three classrooms were still

using the Instructional Concepts Program and had not begun the Communication Skills Program.

	FYCSP-regular	FYCSP-tryout (scannable)
#/sheets	1	1
size of sheet	11" x 17"	8½" x 11"
#/pages	4	2
#/items/page	5	10
paper stock	refined newsprint 40 pound book	60 pound offset white Mustang with Vellum finish
ink	black	black plus drop-out blue for marking boxes

Figure 1. Comparison of tryout materials with Criterion Exercises

C. Data

Data comprised marks made by pupils on Criterion Exercise response sheets. Darkness of mark, direction of pencil stroke, multiple, missing, and crossed out responses, as well as stray marks were counted. Amount of test taking time and observations on teacher and pupil behavior were also recorded.

D. Analysis

Three types of analyses were conducted: 1) an examination of the manner in which response positions were marked. This included the pencil direction used to mark the response, the number of multiple marks, stray and missing marks, and changes in response choice; 2) an analysis of the Digitek DM 100 scanner's ability

to read the pupil marks entered in the response positions; and 3) notation of pupil and teacher behavior during test administration, plus SWRL observer reactions.

Tables 1-3 present an analysis of marks made on the Criterion Exercises. The percentage figures for all measures other than stray marks refer to item (Item N = 20 for all forms). Stray marks are reported by average number per test sheet. For each exercise sheet, there was approximately one stray mark, which would be read by the scanner. Such marks must be erased by clerical help before the exercises are read. The percentage of total items that contained multiple marks ranged from 6.3 percent for the square boxes to 3.1 percent for the vertical. Horizontal marking boxes produced a total of 17 unmarked responses, or 3.4 percent of all items. The other two forms produced a much lower percentage. The vertical box exercises showed a total of 16 response changes (indicated by crossing out the unwanted response).

Table 4 presents a comparison of older (five years and above) versus younger (below five years) pupils in the one class, using the horizontal marking boxes. Younger pupils (under five years) made more stray marks, multiple marks, mark changes, and left more items unanswered.

Table 1. Analysis of pupil marks when vertical response boxes were used. Pupil N = 36.

DESCRIPTOR	N	%	$\bar{X}$ [a]
Stray Marks	76	-	1.06
Multiple Marks	22	3.1	-
No Mark	7	1.0	-
Mark Changed	16	2.2	

[a] Average per side

Table 2. Analysis of pupil marks when horizontal response boxes were used. Pupil N = 25.

DESCRIPTOR	N	%	$\bar{X}$ [a]
Stray Marks	61	-	1.02
Multiple Marks	24	4.8	-
No Mark	17	3.4	-
Mark Changed	3	0.6	-

Table 3. Analysis of pupil marks when square response boxes were used. Pupil N = 15.

DESCRIPTOR	N	%	$\bar{X}$ [a]
Stray Marks	5	-	.17
Multiple Marks	19	6.3	-
No Mark	2	.7	-
Mark Changed	1	.3	-

Table 4. Analysis of pupil marks when horizontal boxes were used (older versus younger pupils).

DESCRIPTOR	GROUP	N	%	$\bar{X}$ [a]
Stray Marks	Younger	43	-	1.95
	Older	18	-	0.64
	Total	61	-	1.02
Multiple Marks	Younger	19	8.6	-
	Older	5	1.7	-
	Total	24	4.8	-
No Mark	Younger	17	7.7	-
	Older	0	0.0	-
	Total	17	3.4	
Mark Changed	Younger	3	1.3	-
	Older	0	0.0	-
	Total	3	0.6	-

An effort was made to determine how pupils filled in the response boxes. The teachers were instructed to tell their pupils to fill the boxes in completely, making sure that the marks were dark and shiny. They were not told the manner in which they were to make their mark. Table 5 shows the number of boxes filled in by marks judged to be vertical (V), horizontal (H), circular (C), or other (O). "Other" included combinations of the first three, basically. When presented with vertical boxes, pupils marked 93 percent of the response positions with vertical marks. Sixty-seven percent of the horizontal boxes were marked in a horizontal manner. When square boxes were used, 45 percent of the marks were vertical, three percent horizontal, and 39 percent termed "other."

Table 5. Pupil marking direction with three types of response boxes.

Shape of Response Box	Vertical				Horizontal				Square			
Marking Direction	V	H	C	O	V	H	C	O	V	H	C	O
Number	683	0	10	38	33	374	3	135	141	10	38	124
Percent	93	0	1	5	6	67	0	26	45	3	12	39

Response sheets possessing vertical boxes were read by the Digitek 100 DM scanner to determine: 1) whether pupils were able to mark in the appropriate positions, and 2) whether pupils were able to make marks dark enough to read by the machine. Nineteen errors were detected in reading 750 marks, an error rate of 2.5 percent. Fourteen of the errors were due to marks that were too light, leaving five, or 7/10 of one percent unexplained "misreadings" by the scanner. Since the horizontal and square response forms were not printed to tolerances required by the scanner, they were not considered in this part of the evaluation.

Observations recorded by SWRL observers are listed below.

- Pupils seemed happy to use pencils. For many of them it was the first time that they had used any writing instrument other than crayons in the classroom.

- By the third item the pupils started to mark the appropriate answer without specific instructions from the teacher. That is, once the appropriate cues were given they did not need to be told to fill in the box.

- When the children were reminded after item three to make their boxes dark and shiny many of them went back to items one and two to make sure that the boxes they had filled in were shiny. Repetition of instructions is helpful in eliciting appropriate behaviors.

- Some teachers felt that there are too many rows on the test, but that with training the pupils could learn how to take the Criterion Exercise. They agreed that a practice exercise similar to the practice Criterion Exercise used in FYCSP would be a great help in the test-taking process.

- It was noticed that several of the pupils, especially the younger ones, turned the page one-half turn so that they could fill in the horizontal boxes by making vertical marks. Also, several students curled their hands, so that when they filled in the horizontal boxes they were still making a vertical mark. More than one pupil was noticed to outline the horizontal box before filling it in.

- One teacher indicated that the marking quality of the pencils was not consistent. A check showed that some pencils <u>could not</u> make dark marks.

- Testing time including directions and practice was approximately 20 to 25 minutes.

Conclusions

While the study was preliminary, several cautious conclusions can be drawn. The most important is the fact the Kindergarten pupils appear to be able to handle a ten item per page two-sided Criterion Exercise. Observation indicated that the main difficulty is that of identifying and maintaining the proper row on which to make the response. With few exceptions, marks made by pupils were sufficiently dark and complete to be read by the optical scanner. The problem of light marks was traced in some cases to the quality of the lead in the primary pencils.

Multiple marks, i.e., two or more boxes per item filled in, cannot be interpreted for correct response by the machine, since all marks are read. While a human may be able to decide which response the pupil did intend as his correct answer and may be able to remove the inappropriate response by pre-processing, it is sometimes difficult or impossible to determine which response is intended. Assuming that the pupil intended to make only one choice, two possible reasons exist for multiple marks: 1) the pupil did not know how to cross out the incorrect response (It was noted in classroom observation that many pupils do not know how or were not able to mark a large X); or 2) the pupil did not know or remember that he had to cross out the incorrect response. Stray marks will always be a problem with scannable sheets. The best resolution to this situation appears to be reminding the pupils not to make extraneous marks on the paper.

Missing responses may have two causes: 1) the pupil could not find the proper row on the page in which to fill in his answer; or 2) the pupil did not know which answer to fill in after he had identified the row.

The direction in which pupils filled in the response boxes appears to be guided by the shape of the box. Over 90 percent of the marks in the vertical boxes were vertical and approximately two thirds of the horizontal boxes contained horizontal marks. It is interesting to note that 45 percent of the pupils filled in the square boxes with vertical marks, while only three percent of the pupils used a horizontal mark. It does appear, however, that pupils could be taught to use either horizontal marks or vertical marks that are dark and complete enough to be read by an optical scanner. Pupils used square boxes effectively, but the response area was so large that filling in the box became almost a coloring exercise. Smaller square boxes would seem more acceptable.

Suggested Revisions

The following suggestions should eliminate most of the problems encountered. 1) The initiation of a practice Criterion Exercise should familiarize pupils with the ten-item page and the necessity of filling in response positions completely with marks that are dark and shiny. 2) Teachers should check during the administration of the Criterion Exercises to make sure that pupils are on the right row and that marks are dark and complete. 3) To help correct the problem of

multiple marks teachers should demonstrate how to cross out a filled-in box and remind pupils once or twice during the administration of the Criterion Exercise to cross out any unwanted responses. A second possible alternative is that of issuing erasers to pupils. In one classroom observed, pupils used erasers with success. 4) Teachers should remind pupils not to make stray marks on the response sheets, and should check during the administering of the Criterion Exercise to make sure that pupils are marking response positions only.

Further Research

This study produced encouraging answers to the four questions addressed. However, the results must be termed preliminary. The following areas should be investigated in depth:

1. the effect of several forms design on pupil test taking behavior;
2. the development and refinement of training procedures that produce appropriate teacher and pupil response during assessment;
3. the cost for various types of Criterion Exercises, including the scannable booklet and test booklet/separate answer sheet format; and
4. the determination of grade levels at which various types of assessment devices may be introduced and used effectively.

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Working Paper 4

RESULTS OF INVESTIGATIONS CONCERNING THE CAPABILITIES OF THE OPSCAN 100DM OPTICAL SCANNER (TN 5-72-05)

Gordon L. Gibbs and Judith Hooper

I. INTRODUCTION

A. Optical Scanning Techniques

Mark Detection

All optical scanning is accomplished through the ability of a scanner to sense varying degrees of reflected light. Whenever there is sufficient contrast between the amount of light reflected from a mark and the amount of light reflected from the surrounding background, an optical scanner can detect the presence of the mark.[1]

Forms Production

Paper. Paper requirements vary enough that a paper that is right for one scanner may be wrong for another. The most important characteristics of paper used with optical scanning equipment are:

1. Reflectance - paper used with optical scanning equipment must be highly reflective to provide good contrast with the marks to be read.
2. Opacity - a minimum opacity is required to provide adequate reflectance.
3. Quality - the paper must be free from dirt, blemishes, and water marks.

Ink. Two basic types of ink are used in the production of scannable forms. Ink used to print marks that can be detected by the scanner is called "scan" ink, and must be non-reflective enough to provide the neces-

[1]Moore Business Forms, Inc. The World of Optical Character Recognition. Niagra Falls, New York, Moore Business Forms, Inc., 1971.

sary contrast in the amount of reflected light. Ink used to print material (e.g., response positions) that is invisible to the scanner is called "non-scan" ink, and must be highly reflective so it reflects almost the same amount of light as the paper on which it is printed.

Printing. The OpScan 100DM internally controls the on/off timing of the reading cells to the marking positions which are referenced from the leading and aligning edges of the form, eliminating the need for timing marks. However, this means that the marking positions must be printed with extreme accuracy which imposes strict tolerances during the printing process.

B. Implications for SWRL

The availability and cost of the special paper and ink, as well as the rigid tolerances that must be maintained during the printing process, have been major obstacles to the production of low cost forms that can be produced by SWRL and optically scanned by the OpScan 100DM optical scanner. The use of a standard paper stock, standard inks, and less restrictive printing tolerances would result in significant cost reductions. However, because SWRL does not possess the means to determine if standard paper and ink meet the specifications set forth by the Optical Scanning Corporation for the OpScan 100DM, and because the effect that less restrictive printing tolerances would have on the scanner's reliability was not known, it was necessary to assess the scanner's ability to mechanically transport and optically scan forms that could be produced by SWRL's Production Services staff and printing equipment, using standard paper and ink.

A series of investigations using the OpScan 100DM were carried out. The objectives of these investigations were to:

1. Determine whether the OpScan 100DM optical scanner can mechanically transport paper that does not comply with the manufacturer's specifications for weight and size.
2. Determine whether standard paper stock possesses sufficient quality, opacity, and brightness to permit it to be used to print forms that are scannable by the OpScan 100DM.
3. Establish validity and reliability indices for the OpScan 100DM.
4. Determine whether standard inks possess sufficient reflectivity to permit them to be used to print forms that are scannable by the OpScan 100DM.

The purpose of this Technical Note is to describe the procedures used to carry out these investigations, and to report their results.

II. INVESTIGATIONS CONCERNING PAPER

A. Manufacturer's Specifications

The specifications for paper, as set forth by Optical Scanning Corporation, are:[2]

> The paper is 8½" x 11" (+ or - .015") 60 lbs., offset, with grain short, and minimum caliper of .005 inches, with Vellum finish. The paper must be 100% woodpulp, free from water-marks and blemishes. The opacity should be 85% or better as read on a Bausch and Lomb Opacimeter. The brightness should be 79% (+ or - 5%) as read on a General Electric Meter.

The first series of investigations were designed to determine whether a standard paper stock possesses the specified characteristics.

B. Weight and Dimensions

Of primary interest was the ability of the OpScan 100DM to batch feed and transport paper that was lighter[3] in weight than the specified 60 pounds without damaging the paper or causing a scanner malfunction. Beginning with a weight of 60 pounds, 100, 8½ x 11 inch sheets of paper were fed into the scanner. The weight of the paper was systematically decreased until the paper ceased to be properly fed into and transported through the scanner's mechanism. The lightest weight paper that passed this test was 45 pound stock.

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[2] Optical Scanning Corporation. Forms design manual: 100DM. Newtown, Pennsylvania, Optical Scanning Corporation, 1971, p. 21.

[3] Heavier paper was not considered since its use could not be expected to result in any cost reduction.

Since none of the paper was precision cut, it was assumed that the dimensions - length, width, and caliper - of the various sheets were representative of standard 8½ x 11 inch stock, and did not necessarily conform to the tolerances set forth by Optical Scanning Corporation.

Based upon the results of this investigation, it was concluded that the OpScan 100DM could successfully batch feed and transport standard (not precision cut) 8½ x 11 inch sheets, ranging in weight from 45 to 60 pounds. However, because the actual scan forms will be subjected to a variety of conditions that may degrade their physical appearance, transportability, and scannability, the use of 60 pound stock is recommended since it would be less subject to wrinkle, tear, etc. For this reason, all further tests were conducted on 60 pound paper stock.

C. Optical Characteristics

The fact that 60 pound paper was successfully batch fed and transported by the OpScan 100DM provided no evidence regarding the paper's optical characteristics; i.e., its finish, quality (cleanliness), opacity, brightness, and reflectivity. It was therefore necessary to determine whether the optical characteristics of a standard 60 pound stock meet the specifications set forth by Optical Scanning Corporation.

Because SWRL does not possess the equipment required to measure these characteristics directly, it was necessary to adopt an heuristic approach in each case.

Finish

Paper with a non-Vellum finish tends to gradually coat the lead of a pencil with a thin film as more and more marks are made on the paper.

The accumulation of this film causes the marks to become lighter and lighter until eventually they can become so light that the scanner is unable to consistently detect them. Paper with a somewhat rough surface is desirable so that it will withstand erasures. For these reasons, and because the cost of paper with Vellum finish is not appreciably different from the cost of paper with non-Vellum finishes, it was decided to retain Vellum finish as an absolute specification.

Because of its availability and relatively low cost, it was decided to use 60 pound offset, white Mustang paper with Vellum finish for all subsequent investigations.

Quality

To determine whether the scanner would detect water-marks or blemishes in this particular paper, a large number of blank sheets were fed into the scanner. After these blank sheets had been scanned, the contents of the magnetic tape, on which the OpScan 100DM recorded the results of the scanning process, were listed using SWRL's line printer. If anything other than a blank had been detected in any marking position, the conclusion must be that the scanner had detected something (i.e., a water-mark or a blemish) "in" the paper. An examination of the tape listing revealed that the scanner had not detected any "marks" on any of the sheets. It was concluded that 60 pound offset, white Mustang paper with Vellum finish does not contain any water-marks or blemishes that can be detected by the OpScan 100DM.

Opacity, Brightness, and Reflectivity

Each of these optical characteristics of paper is related to the scanner's ability to detect a mark that has been made on the paper.

Because SWRL does not possess the instruments required to measure these characteristics directly, the adequacy of the opacity, brightness, and reflectivity of 60 pound Mustang with Vellum finish must be inferred from the measures of the scanner's validity and reliability.

III. VALIDITY AND RELIABILITY

A. Validity

Definition of Validity

The validity with which the OpScan 100DM reads an 8½ x 11 inch sheet refers to the amount of agreement between what the scanner read and what was actually on the paper. Operationally, validity was defined as a decimal number less than or equal to 1.00, obtained from the following equation:

$$V = 1.00 - E_{T/N} \qquad (1)$$

where V = index of validity

E_T = total number of errors

N = number of marks to be read

The value of E_T was obtained by tallying the discrepancies between what the scanner read and what was actually on the paper. Discrepancies (errors) could occur in any one of two ways:

Type I - the scanner failed to detect a mark where one actually occurred.

Type II - the scanner detected a mark where one did not occur.

To more clearly understand each type of error, consider the following examples.

Figure 1 shows a grid consisting of three marking positions in which a mark has been placed in the second position. If the scanner detects no mark in any of the three positions, a Type I error has occurred. If no mark had been made, but the scanner detected one, a Type II error has occurred.

Figure 1. Three marking position grid with a mark in the second position.

From the foregoing discussion, it is obvious that the term E_T in Equation 1 represents the sum of Type I and Type II errors. Algebracially

$$E_T = E_1 + E_2 \qquad (2)$$

where E_1 = number of Type I errors

E_2 = number of Type II errors

Equation 1 may then be written as

$$V = 1.00 - (E_{1/N} + E_{2/N}) \qquad (3)$$

It is obvious from either Equation 1 or Equation 3 that a validity index of 1 represents the ideal case in which no errors occur.

Determination of Validity Index

Procedures. To determine the validity of the OpScan 100DM when reading sheets of 60 pound Mustang, three marking patterns were used. Each pattern consisted of 31 rows, 12 grids per row, three marking positions per grid. The patterns were differentiated on the basis of the location of the mark within the grid. The first pattern consisted of marks placed in the first marking position in each grid; marks placed in the second marking position in each grid made up the second pattern; and the third pattern consisted of marks placed in the third marking position in each grid. The N for each pattern was 372 marks per sheet.

Each pattern was used to mark a sheet of 60 pound Mustang, as well as standard forms provided by Optical Scanning Corporation.[4] These sheets were then fed into the scanner along with a Q-Control Form that programmed the scanner to "look for" the darkest mark in each of the 372 grids on a sheet.

Following the scanning process, the contents of the magnetic tape were listed, and one "pass" was thus completed. Using the same sheets on each pass, three passes were made.

Findings. The results for the OpScan forms supported the hypothesis that the validity index would assume a value of 1.

Totaled over all marking patterns and all passes, the validity index (V) was 0.993. Within marking patterns, the value of V assumed a low of 0.952 and a high of 1.00.

Table 1. Number of errors and the validity index (V), obtained for the 60 pound Mustang.

PASS NO.	MARKING PATTERN	N	NUMBER OF ERRORS TYPE I	NUMBER OF ERRORS TYPE II	V
1	1	372	0	0	1.000
	2	372	5	0	0.987
	3	372	0	0	1.000
2	1	372	0	0	1.000
	2	372	1	0	0.998
	3	372	0	0	1.000
3	1	372	1	0	0.998
	2	372	18	0	0.952
	3	372	0	0	1.000
TOTAL		3348	25	0	0.993

[4] These forms met all specifications set forth by the manufacturer, and were used to provide base line data against which the data for the Mustang paper could be compared. The validity index for these forms was expected to be 1.00.

Conclusions. The fact that the same value of V was not obtained on successive passes using the same marking pattern means that the scanner had made "different" errors on each pass of the 60 pound Mustang paper. For this reason, the value of V cannot be properly interpreted, nor can any inferences be made regarding the adequacy of the optical characteristics of the paper without first investigating the scanner's reliability.

B. Reliability

Definition of Reliability

The reliability with which the OpScan 100DM reads an 8½ x 11 inch sheet refers to the amount of agreement between what the scanner reads on any two passes of the same sheet of paper. Operationally, reliability is defined as a decimal number less than or equal to 1.00, obtained from the following equation:

$$R = \sum_{i=1}^{N} \frac{f(i)}{N} + \sum_{i=1}^{N} \frac{h(i)}{N} \qquad (4)$$

where R = index of reliability

i = i-th response grid; i = 1, 2, . . ., N

N = number of response grids

f(i) = 1 if the scanner registered the same character in the i-th response grid on two passes of the same sheet

f(i) = 0 otherwise

h(i) = 0 if f(i) = 1

h(i) = 1 if f(i) = 0 and the scanner did not register a blank in the i-th response grid on either pass

A value of R equal to 1 represents the ideal case in which the scanner registered the same character in each pair of corresponding grids on two passes of the same sheet of paper.

Determination of Reliability Index

Procedures. Because no errors had been made with the forms provided by Optical Scanning Corporation, it was obvious that the scanner read these forms with perfect reliability (R = 1). Therefore, it was only necessary to compute a value for R when the 60 pound Mustang paper was used.

By comparing the number and type of errors made between each possible combination of three passes, taken two at a time, for the same sheet, hence for the same marking pattern, three values for R were obtained for each pattern. These values were then averaged to obtain a mean value for R, denoted as $\overline{R}$, for each marking pattern. A grand mean for the index was obtained by averaging the three values of $\overline{R}$ and the grand mean was considered to be the best estimate of the scanner's reliability when reading 60 pound Mustang paper.

Findings. The results of the computations are shown in Table 2. The grand mean for reliability was 0.987. Within comparisons and marking patterns, the value of R ranged from a low of 0.954 to a high of 1.000.

Table 2. Values of R obtained by comparing the number and type of errors made between each possible combination of three passes, taken two at a time, using three marking patterns on 60 pound Mustang paper.

MARKING PATTERN	N	PASS 1 v PASS 2 R	PASS 1 v PASS 3 R	PASS 2 v PASS 3 R	$\bar{R}$
1	372	1.000	0.997	0.997	0.998
2	372	0.989	0.954	0.954	0.965
3	372	1.000	1.000	1.000	1.000
GRAND MEAN					0.987

Conclusions. Having obtained measures of the OpScan 100DM's validity and reliability, the combined implications can be discussed.

To provide a single measure of the scanner's capability an algebraic product was formed. It was obtained by multiplying the reliability grand mean (.987) by the total validity (.993). The resultant product (.980) was considered to be the best estimate of the scanner's capability when reading 60 pound Mustang paper.

Based upon these results, and those of previously described tests, it was concluded that 60 pound offset, white Mustang paper with Vellum finish possesses adequate opacity, brightness, and reflectivity; is free from water-marks and blemishes that can be detected by the scanner; and can be batch fed and transported without being damaged or causing a scanner malfunction.

C. Cost Factors

Purchased Forms

Based upon prices quoted by Optical Scanning Corporation, Besel[5] found that the cost per test per pupil for printing a single sheet, two page test varied inversely with the number of pupils involved. When 100,000 pupils were considered, the cost per test per pupil was 1.4 cents. An increase in the number of pupils would result in no appreciable cost reduction. When 5000 pupils were considered, the cost per test per pupil became 8.1 cents, and further reductions in the number of pupils considered would result in additional increases in cost.

SWRL Produced Forms

Computations showed that the cost per test per pupil was 1.2 cents when 100,000 pupils were considered, and 1.3 cents when 5,000 pupils were considered.

These figures indicate that scannable forms can be produced by SWRL, in both large and small quantities, at a cost significantly less than that quoted by Optical Scanning Corporation.

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[5] Besel, Ronald. Scannable Test Forms for IMS - Version 3 Tryout. SWRL, Final TN draft, June 24, 1971.

IV. INVESTIGATIONS CONCERNING INK

A. Manufacturer's Specifications

Having established the fact that 60 pound offset, white Mustang with Vellum finish can be used as the paper stock for scannable forms, the next step was to determine the kind of ink and/or the production process that could be used by SWRL to print such forms.

The specifications regarding the ink used to print forms, as set forth by Optical Scanning Corporation, are:[6]

> All ink used to print the forms require a reflectance level of 48 millivolts as read on Kidder Mark Read Tester (MR8)... Response blocks and any material in these blocks should be screened 30% at 133 lines per inch.

B. Xerography

It was decided to determine whether the OpScan 100DM would detect images produced by a Xerox machine. Using a Xerox model 2400 copier, several copies of the Weekly Log[7] were made on 60 pound Mustang. Along with an appropriate Q-Control Form, these Xerox copies were fed into the scanner, and the contents of the tape were listed and examined.

The extremely large number of Type II errors (detection of a mark where none was supposed to occur) indicated that the scanner had detected the Xerox images. In addition, the number of Type I errors (failure to detect a mark where one appeared) suggested that the registration achieved by the Xerox model 2400 was imprecise and the marking positions and the scan head were not synchronized.

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[6] Optical Scanning Corporation. Op. cit., p. 21.

[7] A scannable form used during the 1968-69 tryout of FYCSP.

Based on these findings, it was concluded that forms produced by current xerography processes cannot be correctly read by the OpScan 100DM.

C. Standard Inks

Unscreened

A prototype criterion exercise response sheet was developed and given to Production Services for art layout and reproduction. Using blue ink, copies were printed on 60 pound Mustang. Unmarked sheets were fed into the scanner and the tape was listed. The number of Type II errors that appeared on the listing indicated that the scanner had detected the ink.

Screened

The same format was used to print additional response sheets, using red, green, and blue ink. However, on this occasion the line delimiters of the marking positions were screened to the manufacturer's specifications (30 percent at 133 lines per inch). These sheets were tested in the same manner as described in the preceding paragraph. The results indicated that the scanner did not detect the delimiters of the marking positions.

The results of all above tests indicated that a standard blue, green, or red ink must be screened to the manufacturer's specifications. However, because SWRL's Production Services had been unable to accomplish this screening, but had to have it done by the Government Printing Office, it was concluded that the forms could not be produced by SWRL using standard ink.

D. Specialized Inks

The previous tests had demonstrated only that screening was required when the reflectivity criterion had not been met. The need for screening when the criterion of reflectivity is met was still in question. Conversations with a representative of Gans Ink Company suggested that reflectivity was both a necessary and sufficient criterion. It was therefore decided to test an ink whose reflectance level was known to be greater than 48 millivolts.

Gans Ink Company provided Production Services with the serial number of a commercially available ink, commonly known as "drop-out blue," whose reflectance level was known to be greater than 48 millivolts. Using this ink (unscreened) additional copies of the prototype response sheet were printed and tested. The results of this test indicated that the scanner did not detect the drop-out blue ink. It was concluded that scannable forms could be produced by SWRL's Production Services, using drop-out blue ink to print any material that was to appear within a marking position.

V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A. Summary

Tests were conducted on the OpScan 100DM optical scanner to accomplish the following objectives:

1. To determine whether the scanner can mechanically transport paper that does not comply with the manufacturer's specifications for weight and size.
2. To determine whether standard paper stock possesses sufficient quality, opacity, and brightness to permit it to be used to print forms that are scannable by the OpScan 100DM.
3. To establish validity and reliability indices for the OpScan 100DM.
4. To determine whether standard inks possess sufficient reflectivity to permit them to be used to print forms that are scannable by the OpScan 100DM.

To accomplish the first objective, sheets of standard 8½ x 11 inch paper were fed into the scanner and their passage through the paper transport mechanism was observed. Beginning with a weight of 60 pounds, the weight was reduced until the paper was no longer properly transported. The lightest weight paper to pass this test was 45 pound.

The quality (cleanliness) of the paper was tested by passing through the scanner sheets of paper that were known to be free from visually observable marks. Any mark registered by the scanner would then have to be the direct result of a water-mark or blemish in the paper. All paper tested was found to be free from such water-marks and blemishes.

Because opacity and brightness could not be measured directly, they had to be inferred from the results of tests of the scanner's validity and reliability. The best estimate of the scanner's validity was considered to be the value V obtained from the following equation:

$$V = 1.00 - (E_{1/N} + E_{2/N})$$

while the best estimate of the scanner's reliability was considered to be the value R obtained from the following equation:

$$R = \sum_{i=1}^{N} \frac{f(i)}{N} + \sum_{i=1}^{N} \frac{h(i)}{}$$

The obtained values, V = .993 and R = .987, were then multiplied to provide a single value, .980, which was considered to be the best estimate of the scanner's capability.

Finally, the scanner's ability to detect any or all of a variety of inks was tested by scanning prototype response sheets that had been printed with each of the inks, both screened and unscreened, in question. It was found that standard blue, red, and green inks all must be screened to the manufacturer's specifications to prevent them from being detected, while "drop-out blue" cannot be detected, even if it is not screened.

B. Conclusions

The results of the tests support the following conclusions:

1. The OpScan 100DM can successfully batch feed and transport standard cut, 8½ x 11 inch sheets, as light as 45 pounds.
2. Paper stock with Vellum finish is preferable to paper with a non-Vellum finish.
3. The OpScan 100DM cannot detect water-marks or blemishes in 60 pound offset, white Mustang paper with Vellum finish.

4. The capability of the OpScan 100DM when reading 60 pound offset, white Mustang paper with Vellum finish is sufficiently high (i.e., .98) to allow its use as the stock on which scannable forms are printed.
5. The reflectance level of standard blue, red, and green inks, when screened 30 percent at 133 lines per inch, and of unscreened drop-out blue, is sufficiently high to permit their use in the printing of scannable forms.
6. The cost of producing scannable forms "in-house" is significantly less than that quoted by Optical Scanning Corporation.

C. Recommendations

Based upon the findings and conclusions, the following recommendations are made:

1. All scannable forms are to be printed on standard cut, 8½ x 11 inch sheets of 60 pound offset, white Mustang paper with Vellum finish.
2. All printed material that appears in a marking position on any scannable form be printed using the unscreened, drop-out blue ink. All other printed material should be printed using a standard, unscreened, ink.
3. All scannable forms be produced by SWRL's Production Services.

Working Paper 5

FORMS DEVELOPMENT FOR THE 1971-72 TRYOUT OF IMS VERSION 3 (TN 5-72-44)

Pamela J. Cooper and Gordon L. Gibbs

McManus (TN 5-72-04) has shown that kindergarten pupils can reliably mark machine readable forms. Investigations by Gibbs and Hooper (TN 5-72-05) indicated that SWRL could feasibly produce optically scannable forms for the OpScan 100DM. This created an IMS requirement for the development of forms that possess the following characteristics:

1. Compatability with existing instructional system forms, e.g., FYCSP Criterion Exercises; and
2. Adaptability as source data automation documents.

This document describes the design of such forms prerequisite to the 1971-72 tryout of IMS Version 3. Each form is discussed in turn, presenting its purpose, design objectives, and format development.

FYCSP MATERIALS

Criterion Exercise Sheets

Purpose. The function of the FYCSP Criterion Exercise Sheet is to provide a form on which kindergarten pupils can record their responses to items on a unit test.

Design objectives. The FYCSP Criterion Exercise Sheet must meet certain specifications: (1) similiarity to present format; (2) maintenance of present method of administration; and (3) human readability.

Form development. The original FYCSP four-sided, five-item per page format was reduced for IMS use to a two-sided ten-item per page sheet. Each item is identified by a row indicator that appears in the same

sequence and (unlike the present FYCSP test) on bothe sides of the sheet in each unit. Ten pictures were chosen as row indicators from a list of objects easily identified by kindergarten pupils (Okada and Baker, DM 17).

The IMS FYCSP Criterion Exercise Sheet directions also maintained the present method of administration in that the pupil responds to a teacher-administered test by marking an answer sheet. With the IMS Criterion Exercise Sheet the student darkens a response cell under the appropriate answer.

FYCSP Class Record Sheet

Purpose. The purpose of the Class Record Sheet is to establish and maintain an accurate, updated list of pupils in a class and to associate those names with a pre-established numerical code.

Design objectives. The following design objectives were set up for the Class Record Sheet: (1) ability to record pupil names by class; (2) ease of teacher use; and (3) ability to add and delete pupil names.

Form development. Development of the Class Record Sheet followed the format of existing class rosters. Two identical sheets, a white copy (original) and a yellow copy (SWRL) were printed. Pupils 1-30 are listed on the first side and pupils 31-60 are on side two. Corresponding binary codes, which are used by the teacher to encode the pupil identification numbers on the Criterion Exercise Sheets, are printed on each line of the Class Record Sheet.

Addition and deletion requirements are met easily with the Class Record Sheet. To add a pupil the teacher writes the pupil's name on the first

available blank line. To delete a student, the teacher crosses the student's name off the record sheet and no longer uses that line number.

Class Identification Sheet

Purpose. The Class Identification Sheet has two functions: (1) linking each set of IMS materials to a specific teacher, and (2) adding new pupils to the IMS data base.

Design objectives. The primary objective of the Class Identification Sheet was to provide pre-coded, machine readable information identifying district, school, teacher, class time and grade. A second requirement was the capability of transcribing a pupil's name into a machine readable code when using the ID Sheet as a pupil addition form.

Form development. Separate forms to identify teachers and to update the IMS data base were considered in developing the Class Identification Sheet. These two forms were consolidated to minimize the number of forms and consequently to maximize information contained on the ID Sheet.

Various arrangements of information contained in the form were examined in an attempt to determine the most readable and aesthetically pleasing design. Both lengthwise and upright orientations were designed; the lengthwise format was chosen as more compact and readable.

IMS/LMS FORMS

Criterion Exercise Sheets

Purpose. The LMS Criterion Exercise Sheets for Harper and Row 1 and 2 and Macmillan Bank Street provide a form on which a teacher can record student responses to items on a unit test.

Design objectives. The first objective was to create a form which altered only minimally the present testing and recording procedures used by teachers. Another was to maximize the number of pupil marks to be recorded on each sheet. A third was to minimize the teacher's clerical tasks.

Form development. There were several areas of concern in developing the LMS Criterion Exercise Sheet. One centered on the fact that the LMS test format changes in the later units from five items for each of three outcomes to ten items for one outcome. To accommodate this change two Criterion Exercise Sheets (forms A and B) were developed. This step simplified procedures, but required teachers to match units with the correct form and to code the exercise unit number. Therefore, it was decided to print a single pre-coded form.

Since the pupils respond verbally to the stimuli in LMS, the manner in which the teacher records the response, the number of items per row, and the number of pupils per page became the major considerations.

Outcome numbers were changed from Arabic to Roman numerals to match the output reports and to distinguish them from the item numbers. The position of the outcomes was shifted on the page to enable teachers to code from left to right on each row. Response cells were narrowed to simplify coding. Response cells on the form used with the later units of the Harper and Row programs were adjusted to match the positions on the form for earlier units. This was done to simplify preparation of control forms and to improve the appearance of the Criterion Exercise Sheet.

Since the teacher marks a pupil's incorrect response only, the marking row for that pupil would be blank if all his responses were correct. Therefore, a pupil with 100% correct scores could not be distinguished from a pupil not tested. It was decided to have teachers mark the pupils "TESTED" by darkening a special box at the end of each row.

Class Record Sheet

Purpose. Like the FYCSP Class Record Sheet, the IMS/LMS Class Record Sheet establishes and maintains an accurate list of pupils in a class and associates those names with a pre-established numerical code.

Design objectives. Design objectives for the Class Record Sheet emphasized creating a teacher-usable form for establishing and maintaining the pupil data base.

Form development. Alternative formats centered on the number of pupils per page and the number of sheets used. Like the FYCSP Class Record Sheet, the LMS sheet contains 30 lines per side numbered 1-30 and 31-60. These lines are further divided into six sets of "List Numbers," three List Numbers per side, containing 10 lines each.

Pupil List

Purpose. The IMS/LMS Pupil Lists serve as an intermediary device between the Criterion Exercise Sheet and the Class Record Sheet. The Pupil Lists comprise a set of six folders containing 10 lines each, i.e., List 1 contains lines 1-10; List 2, lines 11-20, etc. On these lines are names of pupils which correspond to the lines on the Class Record Sheet.

Design objectives. Design objectives included creating a reusable record of pupil names and providing a form which would match names on the Pupil List with response rows on the Criterion Exercise Sheet. The addition and deletion features of the FYCSP Class Record Sheet were to be incorporated in the Pupil List.

Form development. The basic format of the Pupil List is an envelope-like single sheet fold-over form. Six copies of the form were designed with pre-printed, computer readable page numbers. Lines were numbered 1-60, to make them correspond to the numbering sequence used on the Class Record Sheet.

Class Identification Sheet

The Class Identification Sheet used for LMS was designed according to the same specifications used for the FYCSP Class Identification Sheet.

LMS MATERIALS, HARPER AND ROW 3

Criterion Exercise Sheet

Purpose. The purpose of the HR-3 Criterion Exercise Sheet is to provide a form on which a student can record his responses to each item on a unit test.

Design objectives. Design objectives required that the IMS form conform to present testing and recording procedures. Ease of use by both teachers and pupils was another factor, as was the inclusion of identification information regarding pupil name, program and unit number.

Form development. The first format for HR-3 involved creating a scannable form which duplicated the existing LMS format. This possibility

was eliminated because each unit contains a different set of sentences and word lists and would require separate optical scanner control sheets for each unit. Another alternative was the use of a generalizable answer sheet, which would have an A-B-C-D indication of response position rather than the response stimulus. Research cited by McManus (TN 5-72-04) suggested that a separate generalizable answer sheet was too difficult for third grade students. Changes made during the development of this form primarily concerned the positioning of the response cells. The final version features a split page with Part I on the left and Part II on the right. Specific response stimuli were used rather than the generalizable sheet (e.g., A-B-C-D).

HR-3 Class Record Sheet

The HR-3 Class Record Sheet was designed according to the same specifications as the FYCSP Class Record Sheet.

HR-3 Class Identification Sheet

The HR-3 Class Identification Sheet is the same form as that used by LMS and FYCSP.

SPECIAL XEROX 660 SCANNER/COPIER FORMATS

The Class Identification Sheet had to be changed for use with the Xerox 660 Scanner/Copier. With the exception of the ID Sheet other forms remained unchanged for content. Some design changes were introduced for machine compatability (e.g., shape of response box). Special forms (i.e., end of class and end of transmission) were designed to meet hardware and software requirements.

Working Paper 6

PEDAGOGICAL SOURCE DATA IDENTIFICATION AND UPDATING ALTERNATIVES (TN 5-72-21)

John F. McManus

Statement of Problem

Automated identification of individual students as they move through an instructional program has been a fundamental but often overlooked obstacle to the development of a user-ready instructional management system. When student performance data are submitted, they must be linked with the name of the person generating the performance. There are many dimensions within which the individual must be identified, such as class, school, and district. The engineering problem may be stated in the following question form:

> What device and procedures can be developed that will link individuals with their performance data in a manner that is reliable, inexpensive, and adaptable for use in an instructional management system?

Definition

Source Data Identification and Updating may be defined as a multi-dimensional classification device and procedure that link input with appropriate portions of an initialized data base.

A three-part operational structure is inferred from this definition:

1. initialization
2. data input
3. updating

Updating possesses at least five capabilities:

1. deleting a pupil,

2. adding a pupil,

3. changing a pupil name or code,

4. changing pupil data where inaccuracies are detected, and

5. creating an inactive file.

Each individual, therefore, must be identified within certain dimensions and then be input as a unique entity into a "data base," most likely on a computer storage medium such as tape or disk. Also, provisions must be made for adding and deleting students during the course of a school year. As each performance record is entered into a computer it must be linked to the appropriate person. Whenever errors in data input are discovered, the ability to correct these mistakes should exist.

What IMS Must Identify

In IMS, the student is the originating source of performance data. Individual names must be coded in a manner that is understood by a computer. Most likely, the identification will be numerical, rather than a one-to-one alphabetic relationship between student name and its corresponding code. Once the individual is assigned a code, he must then be linked logically with some or all of the several identifiers listed below in descending hierarchical order.

1. nation
2. cross-state region
3. state
4. within-state region
5. district
6. area within district

7. school
8. class/grade
9. individual
10. instructional program
11. group within program
12. logical partition of instructional program, e.g., Unit 1, Unit 2, etc.
13. physical partition of input data medium, e.g., Page 1, Page 2, etc.
14. point-in-time, i.e., date.

Identification Specifications

The student identifier and procedures for its use must produce a pupil identification, or code, that possesses the following characteristics:

1. reliability
2. uniqueness along certain dimensions
   a. temporal unit, i.e., how long is I.D. code unique?
   b. physical location unit, e.g., school, district, etc.
   c. . . .
3. ability to link student code with identifiers 1 through 8 in Section III, e.g., when a data base is compiled, a researcher should be able to retrieve scores for a given unit, school, district, etc.
4. machine readability. This is especially important when tests are input by a source automation device, such as an on-site scanner.

5. human readability. The individual name and class/grade should be readable by the user.
6. student usability by Grade N. While it is not determined that students will use the identifier as a matter of general procedure, the device should lend itself to successful student use by a grade level to be determined at a later date.
7. cost feasibility - one to three percent of total student cost for IMS when identifier device is installed on a large scale.

Work to be Completed

The basic task to be performed is the development of a device and appropriate procedures that will produce a unique student identifier (code, name and grade) as described in Section III to the specifications listed in Section IV. Parts of this problem have already been addressed and some solutions have been advanced.

Several questions and their possible answers are presented below.

Question. How much identification material must be generated for each physical unit, i.e., page of input?

Answer. It appears that identifying information from nation to school (Numbers 1-7 in the hierarchy) can be considered one-time entries to a "static" data base. Instructional program identification through page identification (Numbers 10, 12, and 13) are presently handled in the printing process. Computer codes and alphanumeric listings are pre-printed

on each page. (Group within program - Number 11 - is not dealt with in this fashion and remains a special case for this study.) Point-in-time is currently generated as date of output reports. A procedure for generating a date of testing would be desirable.

It would appear, then, under the present operating conditions of IMS that the ability to identify individual and grade/class in both machine and human readable form would meet present requirements for source data identification.

Question. How will the "group within program" identifier be handled?

Answer. In the initialization process, each student can be assigned a group code. During instruction, new assignments to groups can be made and this part of the code may become a dynamically generated variable.

Question. How many instructional systems must be linked to each individual?

Answer. Initially one. Then four, perhaps by midterm during school year 1972-73. The number may eventually reach ten.

Question. How much identification information must appear on each physical partition of input medium, i.e., test sheet?

Answer. Numbers 8-13, with the exception of 11, in the hierarchy - class/grade through page code - should appear in coded and written form on each page of pupil input. When there is a one-sheet, two-sided test, it is sufficient if student name and class/grade appear in human readable form on the one side only.

Question. How are machine readable marks generated on test sheets?

Answer. In two ways. Currently in two programs, students make marks on test sheets to indicate an answer choice. In three other programs, the teacher asks questions of students individually and then marks the response sheets according to correct or incorrect response.

Question. On the teacher-marked sheets, the performance of ten students on a unit test is recorded on a single sheet. The test sheets containing student-made marks measure performance of one student only. Should the identifier device be capable of handling both cases, i.e., student-made and teacher-made marks?

Answer. It is most desirable that this be so. However, if it is determined that one device cannot handle both cases, then the student-marked test sheets should take priority. The lack of ability to make the same marking device compatable to both cases should not impede successful completion of a coding device for student-marked test sheets.

Question. Do the proposed coding criteria allow for following students as they move from class to class, school to school, or district to district?

Answer. At the present time, no. Such capability would be possible by assigning a unique number, e.g., Social Security Number, to each individual and then linking this number to the identification code proposed above. However, a cost and work effort analysis should be performed before SWRL attempts to develop the capability of following every student through his educational progress. A data base could be developed which contains

"pointers" to his previous class identification code and the code of the new class. Procedures for setting this information into the data base would have to be developed.

Question. How "unique" must the pupil code be?

Answer. Not completely decided. At minimum a code should be unique for each student on a given unit test. More likely, the code should be assigned for at least one school year. The question of "location" uniqueness, i.e., a unique number for each individual across school, district or large administrative organization is addressed, but only partially answered above.

Working Paper 7

USER TRAINING FOR THE 1971-72 TRYOUT OF IMS VERSION 3 (TN 5-72-20)

Gordon L. Gibbs

INTRODUCTION

Although the use of IMS in conjunction with an instructional program (e.g., FYCSP, LMS/HR1, etc.) does not alter instructional procedures used by teachers, it does require the use of special materials and procedures to communicate pupils' criterion exercise responses to the system for processing. The purpose of the training sessions was to instruct participating teachers in the proper use of these special materials and procedures.

Participants

A total of 81 teachers in four districts participated in the training sessions. Of this total, 21 teachers were using FYCSP and 65 were using LMS in conjunction with HR1, HR2, HR3, or MBS.

Scheduling

Because the IMS materials and procedures for use in conjunction with FYCSP are different from those for use in conjunction with LMS, separate training sessions were held for FYCSP teachers and LMS teachers. In addition, the LMS/HR3 training was combined with the IMS/HR3 training. Table 1 presents the dates on which training sessions were held.

METHOD

General Procedures

The general training procedures for each session were the same. A verbal overview of IMS, accompanied by an overhead transparency, included

Table 1

Schedule of IMS Training Sessions

District	Program	Date
1	LMS/HR1	Jan. 6, 1972
	LMS/HR2	
	LMS/MBS	
	LMS/HR3	Feb. 24, 1972
2	FYCSP	Jan. 24, 1972
	LMS/HR1	Jan. 20, 1972
	LMS/HR2	
	LMS/MBS	
	LMS/HR3	Feb. 23, 1972
3	FYCSP	Dec. 2, 1971
	LMS/HR1	Dec. 3, 1971
	LMS/HR2	
	LMS/MBS	
	LMS/HR3	Feb. 23, 1972
4	FYCSP	Jan. 10, 1972
	LMS/HR1	Jan. 11, 1972
	LMS/HR2	
	LMS/MBS	
	LMS/HR3	Feb. 28, 1972

a definition of IMS, a statement of its purposes, and a description of what and how IMS would add to the basic instructional system.

Following the overview, an example of each material component, along with a set of directions for its use, was distributed, and the purpose and procedures for its use were described. In appropriate instances, the participants were given an opportunity to practice the proper use of a component.

Each session concluded with a question and answer period during which participants raised questions regarding the use of any of the components. This time was also used to obtain certain initial data from the participating teachers.

FYCSP Training

Procedures and Materials. The general sequence described in the preceding section was followed. The first component to be presented following the overview was the IMS Class Record Sheet. The purpose of the IMS Class Record Sheet (i.e., to establish and maintain an accurate, up-to-date list of participating pupils in the class) was stated. This statement of purpose was followed by a step-by-step description of its use, which included the following points:

1. Identifying information (i.e., teacher, district, school, grade level, and class) will be pre-printed by SWRL.
2. Pupil names can be listed in any order convenient to the teacher so long as no lines are left blank between names.
3. Indication of a group designator is completely at the discretion of the teacher.
4. When a new pupil's name is added, it must be recorded on the next available blank line.
5. If two or more new pupils are added on the same day, they must be recorded in alphabetical order.
6. If any pupil leaves, his name must be crossed off the IMS Class Record Sheet. However, that line does not then become available for recording a new pupil's name.
7. The teacher should retain the original (white) copy of the IMS Class Record Sheet and mail the carbon (yellow) copy to SWRL.

The second component was the IMS Criterion Exercise Sheet. Each of the two functions (recording responses and deleting pupils) for which this sheet could be used was presented separately.

The following points were covered concerning its use by pupils to record their responses to the criterion exercise items:

1. The major differences between it and the regular criterion exercise sheets were pointed out. These were: (1) it is a single 8½ x 11 inch sheet rather than a four page "booklet"; (2) there are ten items per side rather than five; and (3) pupils indicate their response by completely filling in the box under the stimuli rather than marking the box with an X.
2. The sheets must be prepared by the teacher before administering the criterion exercise. This is accomplished by: (1) recording the pupil's name on the sheet, (2) darkening the boxes above the words PUPIL CODE on the IMS Criterion Exercise Sheet that correspond to the numbers in the column on the IMS Class Record Sheet labeled PUPIL CODE and on the same line as the pupil's name.
3. Both sides of the sheet must be marked with the appropriate pupil code, but the name need be recorded only on side 1.
4. Both teachers and pupils must use #2 lead pencils to mark the IMS Criterion Exercise Sheet.
5. New direction cards for administering the criterion exercises would be provided. These directions are the same as the original

ones except the wording has been changed to reflect the need to mark the boxes by completely filling them in.

6. After administering the criterion exercise for a unit, the pupils' response sheets should be sent to SWRL.

Participants were then given the opportunity to prepare two sheets using the first and third names on the sample Class Record Sheet.

The use of the IMS Criterion Exercise Sheet to delete a pupil was presented next, emphasizing the following points:

1. Side 1 of the sheet should be prepared in the same manner as it was to administer the criterion exercise to the pupil; side 2 to be ignored.
2. The box below the word DELETE should be darkened.
3. The sheet should not have any item responses marked.
4. The sheet should be sent to SWRL either separately or along with a set of pupil response sheets.

Following this presentation the participants were given the opportunity to prepare a sheet that would delete the pupil from the sample IMS Class Record Sheet.

The third component to be presented was the FYCSP Practice Criterion Exercise. The following points were discussed:

1. The Practice Criterion Exercise is designed to acquaint pupils with the new format and marking requirements.
2. Its content was selected to place a premium on pupils' marking behavior rather han their selection of the correct response; it is not a test.

3. It should be used at least one day before the administration of the first actual criterion exercise.
4. The script contained in the directions is only suggested wording. Teachers may alter the wording as they see fit provided the basic ideas remain the same.
5. If the quality of pupils' marks deteriorate during the year, the teacher should repeat the Practice Criterion Exercise.

The final component to be presented was the IMS Class Identification Sheet. The Class ID Sheet serves two functions, to identify a set of Criterion Exercise Sheets and to add new pupil names to a teacher's class record.

Using the Class ID Sheet to identify a set of Criterion Exercise Sheets, the following points were emphasized:

1. Each teacher's Class ID Sheet has been specially precoded for her use. Therefore, they should not be exchanged or duplicated.
2. Each time a set of Criterion Exercise Sheets is ready to be sent to SWRL, the teacher should print the date on which the criterion exercise was administered in the appropriate boxes on the ID Sheet. The teacher need not complete the coding grid below these boxes.
3. The Class ID Sheet must accompany the Criterion Exercise Sheets when they are sent to SWRL.
4. Only one Class ID Sheet is required even if different programs and units are included in a set of data for a class.

Using the Class ID Sheet to add new pupil names to a teacher's class record was then discussed. The following points were emphasized:

1. The same restrictions enumerated above apply to this use of the Class ID Sheet.
2. To add a new pupil the teacher should:
   . Record the date on which he was enrolled in the class.
   . Darken the box indicated by the arrow.
   . Print the pupil's name, last name first, in the boxes, leaving a blank between the first and last name.
   . Send the sheet to SWRL.
3. The Class ID Sheet cannot serve both functions of pupil updating and class identification simultaneously.
4. One Class ID Sheet must be used for each pupil to be added.
5. Used as an updating form, the Class ID Sheet need not accompany a set of criterion exercises, but may be sent separately to SWRL at any time.

The presentation of the Class ID Sheet concluded the formal part of each training session. The question and answer period followed.

Participants' Questions. The following questions were raised by participants. The number in parentheses is the number of training sessions in which that question (or one similar to it) arose.

1. Is there any particular order in which pupils' names must be listed on the Class Record Sheet? (1)
2. When should the criterion exercise be encoded? (1)

3. When should we begin to use the IMS Criterion Exercise forms; i.e., how soon? (2)
4. When should the Practice Criterion Exercise be given? (1)
5. Can both the regular and the IMS Criterion Exercise be given for the same unit? (2)
6. How will SWRL know on which line of the Class Record Sheet a new pupil's name has been recorded? (1)
7. How does a pupil change a mark? (3)
8. What should we do if a pupil transfers from one class to another within a school? (1)
9. Will we get the Criterion Exercise Sheets back? (1)
10. Should we wait until we have a complete set of criterion exercises for an entire class before sending them to SWRL? (2)
11. What information will be contained in the reports that we do not already have by hand scoring the criterion exercises? (3)
12. How long will it take to get the information back to us? (3)
13. Should we retest on units already covered? (1)
14. How do we treat absentees? (1)
15. Should pupils who are having difficulty with FYCSP participate in IMS? (2)
16. How do we order additional materials? (1)

LMS Training (HR1, HR2, and MBS)

Procedures and Materials. With the exception of one additional component, the Pupil List, the sequence followed was the same as that for FYCSP.

The IMS Class Record Sheet for use with LMS programs differs from the one for use with FYCSP in that the pupil code is replaced by a pupil list number. There is no difference, however, in the manner in which the two sheets are used; hence, the directions and presentations were the same.

Following the IMS Class Record Sheet, the Pupil List was presented. The purpose of the Pupil List, to establish a one-to-one correspondence between names on the Class Record Sheet and pre-determined rows on the Criterion Exercise Record Sheet, was explained and the following points were emphasized:

1. On each Pupil List, the pupil name on each line must be the same as that on the corresponding line of the Class Record Sheet.
2. Procedures for recording names initially, for adding names to, and for deleting names from the Pupil List are the same as those for the Class Record Sheet.
3. The Pupil List is a permanent device for use by the teacher and should not, therefore, be sent to SWRL.

Following the presentation of the Pupil List, the IMS Criterion Exercise Record Sheet was presented. Its use in conjunction with the Pupil List was discussed, emphasizing the following procedures:

1. Each time a new Criterion Exercise Record Sheet is used with a Pupil List, the Pupil List number must be encoded.
2. If a pupil responds correctly to an item the response box for that item is not marked; if a pupil responds incorrectly, the box is marked.

3. The TESTED box must be marked for each pupil to whom the criterion exercise is given.
4. Any number of pupils may be tested at a time so long as a new Criterion Exercise Record Sheet is used whenever the Pupil List changes.
5. If a pupil is to be deleted, a Criterion Exercise Record Sheet is coded to indicate the Pupil List number on which the pupil's name appears, and the DELETE box in the appropriate row is darkened.
6. After administering the criterion exercise for a unit to a group of pupils the Criterion Exercise Record Sheets should be sent to SWRL.

Participants' Questions. Following the presentation of the Class ID Sheet the initial data collection forms were distributed and participants were given the opportunity to raise questions. The following questions were asked:

1. Once a pupil has been deleted, must the DELETE box continue to be marked on subsequent units? (2)
2. If I use two instructional programs in the same class will I have to treat them as two separate classes? (1)
3. How many pupils should we test before sending the sheets to SWRL? (1)
4. What kind of information will be contained in the reports? (3)
5. How long will it take to get the information back to us? (3)
6. What do we do with the materials we are now using? (1)

7. When should we begin using the IMS materials? (1)
8. Should we list all pupils on the Class Record Sheet or only those that are using the LMS materials? (1)
9. I am using HR2 with third grade pupils. Will that make any difference? (1)
10. Can we erase marks? (1)

HR3 Training

Procedures and Materials. For HR3 the LMS training and the IMS training were combined into one session during which the presentation of the LMS materials and procedures was followed by a presentation of those for IMS. The IMS portion of the training was most similar to that for FYCSP.

Presentation of the Class Record Sheet was identical to that for FYCSP. This was followed by a presentation of the IMS Criterion Exercise Sheet for HR3. With the exception that teachers were reminded to instruct pupils to mark their responses on the IMS answer sheet and not on the LMS "booklet," directions for using the IMS Criterion Exercise Sheet were the same as those for the FYCSP form. The presentation of the Class ID Sheet for HR3 was also the same as that for FYCSP.

Participants' Questions. Following the formal presentation of the IMS components the teachers were given the opportunity to ask questions. The following questions were asked:

1. After a pupil's name has been crossed off the Class Record Sheet will his number (pupil code) be reassigned? (1)

2. Can pupils write their own names on the Criterion Exercise Sheets? (1)
3. Where on the Criterion Exercise Sheets may we hand score them? (1)
4. What does SWRL do with the Criterion Exercise Sheets? (1)
5. Why don't you have scannable forms for the auxiliary exercises? (2)
6. When I use the Class ID Sheet to add a pupil to the class records, why do I have to record the date? (1)

DISCUSSION

General Comments

Presenting each component separately posed some difficulties, especially when two or more components were interdependent. For example, explaining the Pupil Code on the Class Record Sheet for FYCSP was difficult when the participants had not yet been introduced to the Criterion Exercise Sheet on which the Pupil Code is actually used. In addition, especially with large groups of trainees, distributing the sample components individually, just prior to their presentation, was time-consuming.

Although participants were told that there would be a question and answer session following the presentation, many questions were raised and answered during the presentation of the components. Generally, only questions regarding report content, turnaround time, and future development were raised during the question and answer session.

Gathering the initial data directly from the teachers at the conclusion of the training session proved far superior to obtaining it from office personnel prior to the training session.

FYCSP

The IMS materials for use with FYCSP seemed to be well received by the participating teachers. No objections to the additional clerical work were raised, nor did any of the teachers express doubts about the ability of kindergarten pupils to use the scannable answer sheets.

With the exception of the explanation of the Pupil Code, the presentation of the components was straightforward and progressed smoothly from one component to the next. The updating procedures, adding or deleting a pupil name, were the most difficult for the participants to understand.

LMS (HR1, HR2, and MBS)

Again, the IMS materials were well received by the teachers, although there was some initial confusion regarding how SWRL would identify individual pupil's scores when no names appear on the Criterion Exercise Sheets. In addition, some teachers questioned the value of IMS since they would have to continue to hand score the criterion exercises.

As with FYCSP, the updating procedures were the most difficult for the participants to understand. Most of the difficulty centered around the question of how SWRL would know on which line of the Class Record Sheet a new pupil's name has been recorded. In some cases this was not a matter of concern, but was merely an expression of curiosity.

LMS (HR3)

Combining the IMS training with the LMS training created two problems. First, the session was excessively long. It appeared that the participants had had enough for one session after the LMS training was complete. Second, the fact that participants were not familiar with the LMS procedures made it more difficult for them to understand the IMS procedures. Adding to the problem was the fact that some of the components in LMS and IMS have similar names (e.g., LMS Class Record Sheet and IMS Class Record Sheet).

Again, the updating procedures gave rise to the most questions. Contrary to expectations, however, the teachers were unanimous in their belief that third grade pupils would be able to use the separate answer sheets successfully.

RECOMMENDATIONS FOR REVISION

Based upon the observations made during the training sessions, the problems encountered during training, and the questions raised by the trainees, the following recommendations regarding training materials and procedures are made:

1. The use of a slide/tape presentation to introduce the trainees to:
   - the purpose of IMS
   - the component materials of IMS
   - the operational flow of IMS

2. The use of a training package that contains all of the materials to be discussed during training, including:
   . Class Record Sheet
   . Pupil Lists (LMS only)
   . Criterion Exercise Sheets
   . Practice Criterion Exercise (FYCSP only)
   . Class ID Sheet
   . Output Reports
3. The development of an IMS teacher's manual to contain a complete description of the purpose, materials, and procedures. Include also a list of all error messages generated as part of the output reports, the conditions that could cause the message, and the corrective action (if any) that should be taken.
4. The continued use of the special data collection form to gather initial data at the conclusion of the training session.
5. The separation of IMS training sessions from those for LMS.
6. The renaming of some of the IMS components so that they are not confused with any of the LMS components.

Working Paper 8

TEACHER REACTIONS TO 1971-72 IMS SYSTEM EXERCISE (TN 5-72-51)

Judith Hooper and Gordon L. Gibbs

SECTION I: SUMMARY OF RESPONSES

Teacher Training

> Does the present training mode provide teachers with sufficient information to easily carry out IMS procedures? How can it be improved?

The majority of teachers responding to this item (87%) indicated that the training provided sufficient information to easily carry out IMS procedures; however, many teachers would prefer follow-up training in the form of a second "inservice" session and/or a teacher's manual. Comments from teachers suggested a need for more experience using materials and interpreting reports.

General IMS Procedures

> Which IMS procedures added the most clerical work to normal classroom operations?

Listing and updating pupil names on the Class Record Sheet was the most time-consuming task for teachers using Macmillan-Bank Street (MBS), Harper & Row 1 (HR-1) and Harper & Row 2 (HR-2) reading programs. This was the third most time-consuming procedure for teachers of the First Year Communications Skills Program (FYCSP) and Harper & Row 3 (HR-3).

Of the teachers using MBS, HR-1, or HR-2, 74% checked marking pupil responses on Criterion Exercises and 68% checked the use of Pupil Lists as procedures which added the greatest clerical work to normal classroom operations.

Seventy-eight percent of FYCSP and HR-3 teachers at the debriefing sessions felt that coding pupil numbers and preprocessing Criterion Exercises were the most time-consuming clerical tasks of the IMS program.

Can pupils be trained to mark response cells on the IMS Criterion Exercises?

Teachers did not view training the pupils to handle the mechanics of the Criterion Exercises as a difficult process. The majority of respondents trained their pupils to mark Criterion Exercises in less than 10 minutes. Forty percent of the teachers indicated that they did review marking procedures during the year.

Did teachers permit pupils to change responses on IMS Criterion Exercises?

Almost all of the respondents permitted their students to change answers by erasing, marking an "X" over or circling the unwanted answer. Of the teachers who indicated that they allowed students to change answers, almost three-fourths of the HR-3 instructors and more than one-third of FYCSP teachers had pupils erase.

Output Reports

Did teachers receive reports and use them?

Most teachers received reports (98%) through their principal, but only 39% of the respondents indicated they used the reports. Of these teachers, most used reports to plan instruction and to evaluate pupil performance.

What was the turnaround time for reporting?

Turnaround time was measured in weeks. Almost 60% of the responding teachers indicated they received reports approximately one to three weeks

after mailing, and others indicated they received them only after one to two months.

How would teachers improve upon reports?

Three suggestions were repeatedly offered by teachers:

1. Provide cumulative information for each pupil.
2. Include diagnostic and prescriptive suggestions.
3. Offer "same day" or "one day" turnaround time.

Were error messages understandable and accurate?

Error messages were not satisfactory to more than one-third of the responding teachers. Most felt that messages were confusing or inaccurate.

Acceptance of IMS

Would teachers use IMS for other courses if it were available?

Sixty-nine percent of the respondents indicated they would use IMS with other courses and several suggested using IMS for mathematics. Approximately one-third of the teachers answering this item did not think that IMS was helpful to them and they would not utilize it in other subjects.

SECTION II: COMMENTS

Teacher Training

1. Comments made on the questionnaires and at debriefing sessions indicate that teachers do not clearly understand the distinction between the instructional programs and IMS. In order to receive accurate feedback from teachers, this distinction needs to be stressed during training.

2. Teachers prefer having the opportunity to use IMS procedures and receive reports before training is completed. One solution is incorporating into training simulations of problems likely to arise in the classroom. A second solution is providing an introduction to IMS with a manual or an inservice session and follow-up with stand-up training shortly after the teachers' first experience with IMS in the classroom.

IMS Procedures

1. Few teachers expressed disapproval about additional clerical work associated with IMS. Since the relatively simple task of completing and updating Class Rosters was the most time-consuming procedure for teachers using constructed-item tests, IMS procedures do not appear to be a burden to this group. Teachers using pupil-marked Criterion Exercises noted that coding and preprocessing were the most time-consuming operations. Since these are repetitive tasks, some improved method of precoding and preprocessing that reduces teacher workload would be highly desirable.
2. Results from this tryout indicate that pupils in kindergarten and third grade can be taught to mark the IMS scannable answer sheets. Most marking problems appear to be due to factors such as pencil quality and the size of response cells rather than the students' ability to mark forms as presently designed.
3. The problem of allowing pupils to change answers does not appear to be as difficult as expected. The fact that one-third of the

responding FYCSP teachers allowed pupils to erase responses suggests that even kindergarten pupils may be able to handle this motor task, given training and a supply of erasers.

Output Reports

1. The communication systems appear to be working but the turn-around appears to be at the low end of the reasonable operating range of each ComSys. Modifications in other elements of IMS appear likely to increase the efficiency of each ComSys.
2. Error messages need to be simplified. In addition, the source of some error messages lies in the scanning operation rather than in teacher or pupil behavior. These messages are sent to teachers and may be causing some confusion. Systematic checking procedures and instant communication with scanner operators would improve this condition.

Acceptance of IMS

The fact that one-third of the responding teachers indicated that they would not use the Instructional Management System with other course-work is not surprising since 60% of the teachers reported that they did not use the reports. Greater attention is required to the architecture of the information provided in IMS reports to teachers and to the other audiences that IMS-Version 3 addresses.

SECTION III: SUMMARY OF QUESTIONNAIRE ITEMS

The following are teacher responses to the IMS evaluation form. Data have been aggregated by district.

Fifty-six evaluation forms were returned: District A (13); District B (16); District C (20); District D (7).

Teacher Training

1(a)	Did you attend the IMS training session?	TOTAL	YES	47	(87%)	NO 7	(13%)
		District A		13	(100%)	0	(0%)
		District B		13	(93%)	1	(7%)
		District C		15	(75%)	5	(25%)
		District D		6	(86%)	1	(13%)
1(b)	If so, did training provide you with sufficient information to easily carry out procedures?	TOTAL	YES	31	(67%)	NO 15	(33%)
		District A		8	(67%)	4	(33%)
		District B		5	(42%)	7	(58%)
		District C		13	(81%)	3	(19%)
		District D		5	(83%)	1	(17%)

2. How would you improve training procedures?

Provide a manual (3)
Follow-up training session after teachers have used materials (7)

"Actually take a sample of each situation and let us respond (e.g., tape recording of child's reaction)"

"An introduction sheet of the program to review before our initial meeting would be most helpful."

"Giving less information with the introduction of the program then gradually give out other information with short meetings. It would also be better to start this at the beginning of the school term or start of book."

"By training for each part separately."

"Simplify-organize: a) how to score; b) send in material."

"A meeting of teachers with a representative from SWRL to go over computer sheet of first scores."

"The suggestions that are given by Mr. Gibbs."

"Supply teacher with more specific problems to be alert before tripping the problem."

"Would be improved by becoming more familiar with materials."

"Have a dry run."

"Perhaps have the varied tests given to teachers, so we can relate to what we are to be doing."

"I found the manual helped me and left no unanswered questions."

"Give teachers credit for knowing a little of what constitutes learning to read and appropriate application of that skill in all learning areas."

"It seems necessary to 'dig it out' for one's self."

IMS Procedures

3. Listed below are the specific IMS procedures. Check the four that added the most clerical work to your normal classroom operation. (Percentage of responses for this item are calculated from the total number attending debriefing sessions and for whom the items below apply)

   a. listing and updating names on the Class Record Sheet
   b. adding pupils to class records
   c. deleting pupils from class records
   d. marking the date of testing
   e. training students to complete tests (FYCSP, HR-3)
   f. coding pupil numbers (FYCSP, HR-3)
   g. preprocessing exercises before mailing (FYCSP, HR-3)
   h. using Pupil Lists (HR-1, HR-2, MBS)
   i. marking pupil responses on Criterion Exercises (HR-1, HR-2, MBS)

	District A	District B	District C	District D	TOTAL	
a)	5	5	11	0	21	(38%)
b)	3	2	5	0	10	(18%)
c)	3	2	1	2	8	(14%)
d)	1	1	2	1	5	(9%)
e)	3	3	6	0	12	(32%)
f)	4	10	11	4	29	(78%)
g)	5	13	9	2	29	(78%)
h)	6	2	5	0	13	(68%)
i)	4	2	7	1	14	(74%)

Other: passing out correct pencils (3)
seating students to avoid copying (2)
comparing teacher scores with IMS scores (3)
no increase (2)

Procedures for Selected Response Tests (FYCSP, HR-3)

4. How long did it take you to train students to correctly mark Criterion Exercises?

___ a. less than 10 minutes
___ b. 10-20 minutes
___ c. more than 20 minutes

	a	b	c
TOTAL	16 (62%)	7 (27%)	3 (12%)
District A	3 (100%)	0 (0%)	0 (0%)
District B	4 (67%)	2 (33%)	0 (0%)
District C	7 (58%)	2 (17%)	3 (25%)
District D	2 (40%)	3 (60%)	0 (0%)

5(a) Did you ever retrain pupils on procedures for marking Criterion Exercises?

	YES		NO	
TOTAL	17	(40%)	25	(60%)
District A	1	(14%)	6	(86%)
District B	7	(50%)	7	(50%)
District C	6	(38%)	10	(63%)
District D	3	(60%)	2	(40%)

5(b) If so, how many times?

	Once	Twice	Several
TOTAL	4 (36%)	2 (18%)	5 (45%)
District A	1	0	0
District B	2	0	2
District C	1	2	1
District D	0	0	2

6(a) Were pupils allowed to change answers on Criterion Exercises?

	YES		NO	
TOTAL	33	(89%)	4	(11%)
District A	4	(67%)	2	(33%)
District B	14	(100%)	0	(0%)
District C	10	(83%)	2	(17%)
District D	5	(100%)	0	(0%)

6(b) If yes, how?

a. eraser
b. X out or circle
c. other

	a	b	c
TOTAL	19 (58%)	14 (42%)	0 (0%)
District A	4 (100%)	0 (0%)	0 (0%)
District B	5 (36%)	9 (64%)	0 (0%)
District C	7 (70%)	3 (30%)	0 (0%)
District D	3 (60%)	2 (40%)	0 (0%)

7(a) Did you receive IMS Reports?

	YES		NO		SOME	
TOTAL	41	(80%)	1	(2%)	9	(18%)
District A	9	(75%)	1	(8%)	2	(17%)
District B	12	(86%)	0	(0%)	2	(14%)
District C	18	(90%)	0	(0%)	2	(10%)
District D	2	(40%)	0	(0%)	3	(60%)

7(b) How many days did it usually take to receive reports from the time you mailed the tests?

	< 1 week	1-2 weeks	2-3 weeks	More than 3 weeks
TOTAL	2 (4%)	14 (30%)	11 (24%)	19 (41%)
District A	0 (0%)	6 (60%)	1 (10%)	3 (30%)
District B	1 (7%)	5 (36%)	1 (7%)	7 (50%)
District C	0 (0%)	2 (12%)	9 (53%)	6 (35%)
District D	1 (20%)	1 (20%)	0 (0%)	3 (60%)

8. Were reports accurate?

	YES		NO	
TOTAL	38	(72%)	15	(28%)
District A	11	(85%)	2	(15%)
District B	6	(40%)	9	(60%)
District C	16	(84%)	3	(16%)
District D	4	(80%)	1	(20%)

9(a) Did you use reports?

	YES		NO	
TOTAL	21	(39%)	33	(61%)
District A	1	(8%)	12	(92%)
District B	5	(33%)	10	(67%)
District C	10	(53%)	9	(47%)
District D	5	(71%)	2	(29%)

9(b) If yes, how?

a. plan instruction
b. evaluate pupil performance
c. show to parents
d. other

	a	b	c	d
TOTAL	14 (38%)	15 (41%)	5 (14%)	3 (87%)
District A	1 (20%)	1 (20%)	2 (40%)	1 (20%)
District B	5 (50%)	5 (50%)	0 (0%)	0 (0%)
District C	5 (36%)	6 (43%)	1 (7%)	2 (14%)
District D	3 (36%)	3 (36%)	2 (25%)	0 (0%)

10. How would you change reports to make them more helpful to you?

Cumulative Reports (11)

Diagnosis and Prescription (8)

Same day or 1 day reporting (7)

"A quicker and more detailed diagnosis and prescription."

"Cumulative reports for each pupil."

"More specific areas that need extra work. Just tabulated scores only reaffirm what I already knew."

"Availability in shorter space of time."

"Return sooner to us."

"Please have them returned as soon as possible with problem areas diagnosed."

"Accurate, easily managed to see the entire class and individual progress."

"Prescriptions will be very helpful."

"Make complete class list."

"Include class or group averages. Show why a response was marked incorrectly."

"Make them more accurate. Give total class and group averages."

"Make more easily understood at the beginning."

"Improve accuracy of test scores and amount of time taken for processing."

"Give more information on the results of the test. Return scores immediately. Have a meeting to discuss procedures of test when they have failed."

"I would utilize more time on understanding the reports."

"I like to know which ones they missed for practice purposes immediately."

"Have a copy of the children's responses for future reference or instruction."

"Include the number of students who scored 80% or better and the percentage of students who scored 80%."

"Immediate return of scores. Listed suggestions included."

"Let us know what types of things each child missed most. More of a diagnosis of what children are doing."

"Diagnosis of learning problems."

"Cumulative data showing pupils name and each score to date, would be most helpful for remediation and evaluation."

"To get them feedback sooner."

"More accuracy. Include cumulative."

"Having each child's information on one sheet, or an entire class list."

11. Were error messages understandable and accurate?

	YES		NO	
TOTAL	26	(65%)	14	(35%)
District A	6	(75%)	2	(25%)
District B	8	(57%)	6	(43%)
District C	8	(62%)	5	(38%)
District D	4	(80%)	1	(20%)

Comments:

"Too wordy"
"Confusing"

12. Would you prefer automated scoring of tests over scoring them yourself if IMS reports are returned within: (you may check more than one line)

____ a. same day
____ b. 1 day
____ c. 2 days
____ d. 1 week
____ e. 1 month
____ f. I prefer to score them myself

If (f) is checked, please explain why.

	A	B	C	D	E	F
TOTAL	17 (23%)	21 (28%)	13 (18%)	9 (26%)	0 (0%)	14 (19%)
District A	7 (35%)	8 (40%)	3 (15%)	0 (0%)	0 (0%)	2 (10%)
District B	2 (10%)	5 (25%)	0 (0%)	4 (20%)	0 (0%)	9 (45%)
District C	7 (26%)	7 (26%)	7 (26%)	3 (11%)	0 (0%)	3 (11%)
District D	1 (14%)	1 (14%)	3 (43%)	2 (29%)	0 (0%)	0 (0%)

(f) Comments:

"Easier to relate to pupil."

"If they weren't back within 2 days."

"It's much faster. Can do a quick review almost immediately - right after testing."

"I like to know what words or elements or alphabet letters the child has difficulty with."

"I can get immediate results. The students will be able to see their mistakes immediately."

"This way I could provide immediate remedial work."

"I would like to know the part of the test that the child has failed and reinforce those skills, but have the test scored and send results to me."

"I would like to see how the class progressed. I scored the last three because I had not heard from the others. I wanted to know who should take the practice test."

"If I check them myself I can easily understand the progress that a pupil has made and plan for him."

"Faster. I know exactly where I stand immediately so I can plan tomorrow's lesson."

"I can see what children missed instead of just seeing a score. I like immediate scoring (same day)."

"Many of my scores from SWRL IMS were inaccurate; therefore I scored my tests myself anyway before sending them in."

Acceptance of IMS

13(a) Would you use IMS for other courses if it were available?

	YES		NO		MAYBE	
TOTAL	31	(65%)	15	(31%)	2	(4%)
District A	4	(50%)	4	(50%)	0	(0%)
District B	10	(63%)	6	(38%)	0	(0%)
District C	11	(61%)	5	(28%)	2	(11%)
District D	6	(100%)	0	(100%)	0	(100%)

13(b) Why?

+ For Math (4)

+ "Hopefully to pinpoint difficulty of student or concept or skill that needed to be retaught."

+ "Teacher free time, diagnosing."

+ "Yes if the data could be reported swiftly."

+ "It is very helpful altho as any other process, time-consuming. Any program should be started at the year's beginning so as not to have the child respond to weird adjustment at mid semester."

+ "I think that the program was excellent. I regret that I was unable to complete the entire program from start to finish."

+ "Because it helps to evaluate a pupil's progress with each unit."

+ "The children developed a sense of pride in their work when they were told that their test would be checked by computer."

+ "It is an excellent basis from which to build. It is also comprehensive alone."

+ "It would save time in ranking pupil responses."

+ "Because of its thorough organization of subject matter and easy assessment of pupil evaluation for re-teaching or instruction."

+ "If it could score fast as myself it would be beneficial, especially math."

+ "It organized the work and reinforced some of the important words."

+ "It is a basic teaching program utilizing the pupils' learning capacities and skills. A teacher can add to this program in many

ways to allow the student a greater learning experience range and general background information and applications recognitions of learning (behavior changes)."

+ "Would love to see facilities, machines and procedures. A break thru for me - I've always been anti-computer. Would love to be involved in this program next year."

+ "I like having a definite criterion to work from so I know if a child is ready to go on to the next area."

+ "It is an excellent basis from which to build. It is also comprehensive alone."

+ "If remedial work could be provided."

+ "If returned within 2 days."

+ "My children have made broad, upward strides under this system which is tremendous just as it stands especially in vocabulary development and comprehension in reading."

+ "It enables teacher to very accurately determine what the child has and has not absorbed as to a subject and to do remedial work right away, if needed."

+ "Math. Greater possibility for working with individualized instruction."

+ "Cumulative data would be helpful in other areas."

+ "I've really enjoyed working with it."

- "Not in first grade."

- "Too busy."

- "IMS at this point does not help me as a teacher or the child. The only thing it is good for is teaching children how to take tests."

- "There were no benefits for the teacher. I would prefer the handwriting program."

- "Too much clerical work involved. I like the reading program, I like the accountability but I don't like the amount of busy work I'm forced to do."

- "There doesn't seem to be a need for it in my present program."

? "It would depend on the program."

III. Hardware/Software Studies

Working Paper 9

IDENTIFICATION AND DESCRIPTION OF ALTERNATIVE MEANS OF ACCOMPLISHING IMS OPERATIONAL FEATURES (TM 5-72-02)

Ashok Davé

OPERATIONAL FEATURES OF A REALIZABLE IMS CONFIGURATION

SWRL's Instructional Management System (IMS) is designed to collect individual performance data from schools, to process the data, and to provide useful derivative information to persons responsible for some aspect of the pupil's performance (see TM 5-71-01). The operating features of IMS are:

- collecting and sending pupil performance (and other IMS-relevant) data from school sites to processing centers--data collection, input, and transmission
- receiving, scanning, and processing the data, and developing useful information, results, and materials--data reception, scanning and processing
- storing the data and other pertinent information to assist the processing--data/information/materials storage
- receiving and distributing the processed information, results, and materials at school sites--information/results/materials transmission, output and dissemination
- requesting pupil performance (and other IMS-relevant) information, and maintaining and updating this information from school sites--query and information/results/materials retrieval

These operating features of IMS are grouped into three basic physical categories, as shown in Figure 1. The structure of the matrix is flexible. If, for example, the processing center were located at the school site,

Figure 1. Operational Features--Physical Classification Matrix

PHYSICAL CLASSIFICATION / OPERATIONAL FEATURES	SCHOOL SITE	COMMUNICATIONS	PROCESSING CENTER
Data Collection	X		
Data Input	X		
Data Transmission		X	
Data Reception, Scanning, and Processing			X
Data/Information/Materials Storage			X
Information/Results/Materials Transmission		X	
Information/Results/Materials Output	X		
Information/Results/Materials Dissemination	X		
Query and Information/Results/ Materials Retrieval	X		

the communications aspect of the matrix could be partially or completely eliminated. In the same example, data scanning could be carried out at schools, leaving the processing to be done at centers; or, the storage feature could be at school sites as well. Thus, the basic idea behind the matrix is to show that certain operating features of IMS can be conveniently and functionally grouped together. The essential means for carrying out (manually, automatically, or in combination) these features can be classified on a geographical location basis. Figure 2 depicts the closed-loop operation of IMS.

POTENTIAL MEANS OF ACCOMPLISHING IMS OPERATIONAL FEATURES

DATA COLLECTION

This feature concerns the collection of data from the originating sources (e.g., test sheets from pupils). This can be performed in a variety of ways.

Designated Person Collects and Hand-Carries

After each student has marked the test sheet, a designated person collects the sheets from all the sources and hand-carries them in a batch mode to an input device or some other location.

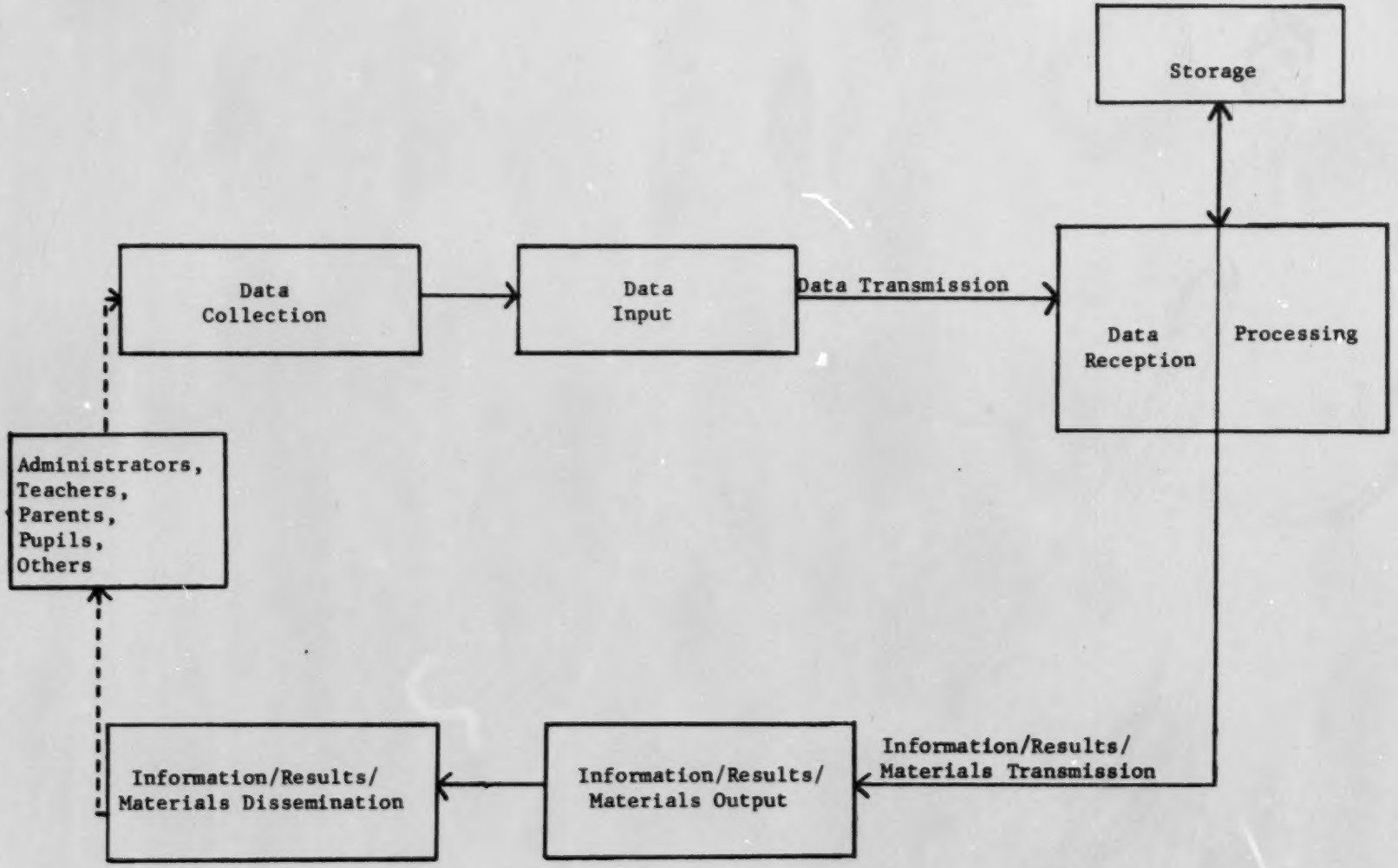
Each Student Hand-Carries

Each student, after completing the test, hand-carries his test either to the input device or some other location where all the sheets are deposited.

Transport Mechanism

A mechanism, such as a conveyor belt or chute, can be used to transport test sheets from the originating sources to a central location or into the input device.

Figure 2. Closed-Loop Operation of IMS



On-Line Interaction

Each student interacts on-line with an input device (thereby eliminating the data collection feature).

DATA INPUT

Data entered at the input device can be transferred onto an intermediate storage medium--as shown in the matrix (Fig. 3). It can then be transmitted over communications lines from any of these media. Therefore, the data entered from a teletypewriter or a CRT (cathode ray tube) device can be recorded onto a paper tape or magnetic tape (e.g., cassette, cartridge). Touch-tone terminals transmit analog audio signals which can be digitized and stored on a magnetic tape. The optical devices generate data-related codes which can be transferred to paper or magnetic tape. Plastic card readers are commonly used for the verification of credit cards. The punched card reader transmits the position of holes in the card in a computer readable form. Battery operable portable data terminals work on the same principle as that of a standard teletypewriter, with the exception, and as the name suggests, that they are portable and can be operated on rechargeable batteries. Human voice input devices, now under development, will enable the user to input data by means of natural or artificial speech. A brief description of these data input devices is given below.

Teletypewriter

A teletypewriter is an electromechanical device that provides facilities for exchanging data and information via appropriate transmission facilities. This device can be either:

Figure 3. Input Devices and Related Intermediate Storage Media

FROM / ONTO	OUTPUT MEDIUM(S)			
Data Input Device*	Paper Tape	Cards	Magnetic Tape	Hard-Copy**
Teletypewriter	X	X	X	X
CRT	X	X	X	X
Touch-Tone Terminal			X	
Optical Mark Reader	X	X	X	
Optical Character Reader	X	X	X	
Plastic Card Reader			X	
Punched Card Reader		X		
Battery Operable Portable Data Terminal	X	X	X	X
Human Voice Input Device			X	

* An input device is generally referred to as a source data input device when it directly captures data for computer processing at the originating source without human intervention with the data. This procedure is generally referred to as Source Data Automation (SDA).

** Hard-copy options extend verification and editing (if required) of raw data.

- a receive only (RO) unit
- or a send and receive unit.

The receive only type does not have a complete alpha/numeric keyboard and only has a mechanism for receiving and printing the information. The send and receive unit can either be a keyboard send-receive (KSR) or an automatic send-receive (ASR) teletypewriter. The KSR provides facilities for originating messages for transmission by the manual operation of a keyboard, and for receiving and printing messages; the ASR has the added facility of transmitting by the reading of a perforated paper tape, and to receive messages and perforate them on tape.

CRT

A cathode ray tube is similar in construction and appearance to the picture tube of monochrome television sets. A light pen or a keboard permits the user to input the data via a CRT terminal, which can either be stored on a paper/magnetic tape and/or transmitted to the computer.

Touch-Tone Terminal

Touch-tone terminals, whether numeric or alpha/numeric, consist of a keyboard. Each key on the keyboard sends a different audible signal. Special equipment at the receiving center is required to receive the series of tones for interpretation, storage, and processing by the computer.

Optical Mark Reader

An optical mark reader reads marks that have been entered on a form in a prescribed location, reads them, and can either transmit the mark

or store it on tape or punch card. In addition to these functions, this type of device can also score, and print limited information on the forms at the input location (see TN 5-71-86 and TN 5-71-90 for further discussion of optical mark readers).

Optical Character Reader

These readers recognize the characters by their pattern, and some of the readers can read hand-printed alpha/numeric data.

Plastic Card Reader

This is an electronic device used to verify plastic credit cards by an on-line link to a computer. The methods of recording data on plastic cards for eventual transference to a computer can be magnetic striping, optical character recognition, punched holes, color bars, or fluorescent sensitivity.

Punched Card Reader

The data to be processed can be key-punched on cards and a card reader can then transmit the data to the computer.

Battery Operable Portable Data Terminal

These terminals are portable and are operable on batteries. Data are entered by depressing the appropriate keys on the keyboard, and the keyed data are automatically recorded on the magnetic tape. A strip printer for printing the data completes this portable terminal configuration.

Human Voice Input Device

A simple illustration of such a device is the ordinary telephone. However, a sophisticated automatic speech synthesis and recognition mechanism is required at the computer end to accept this mode of input.

DATA TRANSMISSION*

This IMS feature is comprised of sending the data which is collected at school to the processing center, which could either be accomplished manually or in an automated mode. Various potential means of accomplishing this feature are described below.

Courier Mail

Data are carried from one place to another by a courier (who can either walk or use a vehicle).

U.S. Mail

The United States postal facilities can be used for transmitting the data to the processing center.

Telephone Lines

The telephone communications lines** are utilized in different ways to transmit data, and depending upon this mode of data transmission,

*Much of the discussion in this section is based on information presented in Telecommunications and the Computer by James Martin, Prentice-Hall, 1969.

**Communications lines fall into one of three categories of speed (Martin, 1969):

1. Narrow-Band: Lines designed for telegraph and similar machines transmitting at speeds ranging, in the U.S., from 45-150 bps.

2. Voice-Band: Telephone channels normally transmitting today at speeds from 600-2400 bps. Speeds up to 4800 are in use....speeds of 7200 and possibly higher can be expected in the near future.

3. Wideband: Lines giving speeds much higher than voice channels, using facilities which carry many simultaneous telephone calls. Speeds up to about 500,000 bps are in use, and higher bit rates are possible if required.

(continued on next page)

they are assigned specific service-names. There are two basically different types of service that the Common Carriers (mainly The American Telephone and Telegraph Company--AT&T, the Bell System, General Telephone and Electronics--GT&E, and Western Union Telegraph Company) offer. One is the public or exchange service which consists of subscriber lines connected to a switching system, as the telephone network. The other is the private line or channel leasing service which consists of full-time leased point-to-point or multipoint lines connecting locations belonging to only one customer. The cost of the exchange service usually consists of toll charges based on the distance and length of connection, and a monthly service charge. The cost of private line service consists of a monthly rental based on the length and type of line. Different services offered by the Common Carriers which provide communication with or without modems are briefly described below.

WATS. The Wide Area Telephone Service permits a subscriber to place calls within a specified area at a flat rate. Monthly charges are based on the radius or area covered and not on the number or length of calls.

TELPAK. This is a private line, "bulk" communications service offered in the U.S. by the telephone companies and Western Union. It transmits high-volume point-to-point communications in various forms--voice, telephotograph, teletypewriter, control, signaling facsimile and data. It can be tailored to provide wideband communications also.

To lower the cost of network communications lines, it is often desirable to attach more than one terminal, or more than one concentrator, to a single leased line. A line such as this with several "drop-off" points is termed a multidrop line. When several devices all share a communication line, only one can transmit at once, though several or all points can receive the same information.

TWX and TELEX. These are the names applied to the teletypewriter exchange services of the Bell System and the Western Union respectively. They provide direct dial point-to-point connections using input/output equipment such as printers, punches, readers, and keyboards.

DATA-PHONE. Through the use of modems, the DATA-PHONE provides for the transmission of data using the regular dial-up telephone network. The same network can also be used for local and long-distance voice communication.

DATA-PHONE 50. Bell System provides this switched wideband data communications service. A subscriber can dial a call and send data at speeds up to 50,000 bps, a 25 fold increase over the "voice-band" DATA-PHONE service.

INFO-COM. Developed by Western Union, INFO-COM is a store-and-forward message or data communications service.

DIAL-PAK. A part of Western Union service, it extends direct computer-to-computer communications using a 48 kHz wideband switched system.

Private-Line Voice Service. This service provides a private voice-grade line for the exclusive use of a particular subscriber. It can be used for either voice communication or data transmission using a modem. The charges for this service are based on a per mile, per month basis.

Telegraph Lines

These lines are separate from the voice-grade network and accommodate speeds from 45 to 150 bps. A DC current modulation technique is usually used to transmit data.

Coaxial Cable

The coaxial cable consists of a hollow copper cylinder, or other cylindrical conductor, surrounding a single wire conductor. A very large number of separate telephone calls can be transmitted together through a coaxial cable system.

Microwave Radio

Like coaxial cable, microwave links can carry thousands of voice channels, and are widely used for the transmission of television. Since these waves require line-of-sight transmission, the antennas which relay them must be at points high enough to be within sight of one another. Privately owned microwave links have also been set up by some corporations.

Satellites

A communications satellite provides a form of microwave relay. Its location in space allows it to relay signals over long distances that would not be possible in a single link on Earth (because of curvature, mountains, and atmospheric conditions). The satellites are powered by solar batteries. Like microwave links on Earth, they can be built to handle several thousand voice channels. It is likely that in the 1970s they will be used as an alternative to the other media discussed for long distance traffic within a country such as the U.S.

Tropospheric Scatter Circuits

Since the troposphere scatters radio waves, it is used for telecommunication links of up to about 600 miles. They utilize very large antennas and a higher transmitter power than microwave circuits. Of the

three--coaxial cables, microwave relays, and tropospheric scatter circuits--microwave relay is the least expensive.

Short-Distance Radio

It is possible that short-distance radio links of the type used in taxis and walkie-talkies will be widely used for computer input and output. A small mobile radio terminal may work in conjunction with a transmitter on a device which is connected to a computer by land line. It may also operate with the public mobile telephone service for vehicles.

Waveguides

A waveguide is a metal tube through which radio waves of very high frequency travel. It is presently under development, but is not used for long-distance communication; it is rarely employed for distances over a few thousand feet. The waveguide, constructed by Bell Laboratories, is capable of carrying no less than 200,000 voice channels in one direction. This system, when operational, will be excellent for data transmission.

Lasers

Operating at the frequency of light, lasers have been successfully used to transmit data from space vehicles. Presently, they are still mostly in the realm of research laboratories for earthbound communications. It seems probable, however, that they will eventually provide the means of building channels of enormous capacity. It has been said that lasers portend a revolution in telecommunications as fundamental as the invention of radio. Lasers of many different frequencies could travel together down the same fiber, and a bundle of such fibers could

occupy one pipe. Such a laser system has the potential ability to carry all the information carried by all of the telephone lines in the world today at the same time!

DATA RECEPTION, SCANNING, AND PROCESSING

This IMS feature is accomplished by using computers.* There are a number of ways to describe and differentiate amongst computers. Aside from cost, internal core memory size, memory cycle time, and word length and structure are perhaps the most distinguishing characteristics of a computer.

The size of internal core memory is a major factor in the computing power of the central processing unit (CPU). The memory is usually organized into words, bytes, or characters which have a fixed length.

Memory cycle timing determines the speed of the computing operations. Cycle time is generally defined as the period of time required for a memory to go through a complete read-write cycle and be prepared to begin the next cycle. The read access time is also an important feature of the memory characteristics. It is the time required for the information output lines from a memory to become stable after the read portion of a read memory cycle.

Memory word size refers to the number of binary digits (bits) that can be retrieved from or stored in the internal memory in a fixed time

*In instances where manual modes (e.g., mail) of data transmission are employed, the reception of data at the processing site would require systematized procedures of receiving, coding, and preparing the data for further processing. Orderly means of filing and documenting would also be important considerations.

interval (usually the memory cycle time). The word size determines the accuracy and efficiency of processing operations.

For IMS purposes, alternative computers will be characterized in three dimensions; on the basis of internal core memory size--expressed in K's (thousands) of words; on the basis of word size--in bits per word; and on the basis of the cost of the computer with the CPU and basic memory--expressed in dollars. According to these three dimensions computers have been classified as mini-computers, midi-computers, and large-computers in the following table (Fig. 4).

Figure 4. Classification of Computers

	INTERNAL CORE MEMORY SIZE (K-words)	WORD SIZE (bits/word)	COST OF CPU & BASIC MEMORY ($)
LARGE	> 64	> 24	> 100,000
MIDI	⩽ 64	⩽ 24	⩽ 100,000
MINI	⩽ 32	⩽ 16	⩽ 40,000

The figures in this table have been derived from recent literature and discussions with knowledgeable persons in this field. Since the cost-capability ratio of computers is increasing at a rapid rate, the

classification base may well be transitory. If so, the direction will inevitably be a downward movement of the first two columns.

DATA/INFORMATION/MATERIALS STORAGE

Storage for IMS data/information/materials can either be an exact copy or a digital medium. Exact copy storage consist of the storage of one or more copies of the original record or document itself (e.g., carbon or duplicated copies in files, bound volumes of printed pages, etc.). With respect to problems of document miniaturization for more compact exact copy reproducible storage, optical memories (e.g., roll microfilm or microfiche) are frequently used. Another approach to document miniaturization with exact copy reproduction capabilities involves the use of video tape.

Digital storage of data entails digitalization, compaction, and recording of data on some medium. Alternative digital storage media are briefly described below.

Magnetic Drum

The memory element for the magnetic drum is a cylinder with a magnetizable external surface on which data can be read or written by magnetic recording techniques. In the fixed head version, the heads are fixed in the drum, providing one head for each track. In moveable-head drums, one read/write head exists for a group of tracks and all the heads are moved by a mechanical positioner. Drum memories are built-in, i.e., are non-removable from the computer system.

Magnetic Disk

The magnetic disk is a flat, circular plate with one or both magnetizable surfaces which rotate about the axis perpendicular to the

centers of its flat sides. More than one disk can be stacked along this axis and rotate on a common shaft. The read/write head(s) may either be fixed or moveable. When the disks are non-removable, they are known as disk drives or disks. Removable disks are generally known as disk-packs or disk-cartridges.

Magnetic Card

Data may be stored by selective magnetization of the surface of this card. The card is usually made of flexible plastic material with a coated surface on one side on which data may be stored in tracks. Magnetic card memories are usually removable-media, since the card stack can be easily changed.

Magnetic Tape

The storage here is on a loop of magnetic tape that is driven past a read/write head for information retrieval/data recording. Many loops form a cartridge, and there can be one or more read/write heads per loop, positionable across the tape. The cartridge is usually removable.

Punched Card

By means of holes punched in a card, data are fed into the computer. These cards also serve as a storage medium.

Punched Tape

This is a paper or plastic ribbon having one longitudinal row of small feed holes and a number of rows of larger data processing holes. As with the punched cards, data, once recorded, is permanent and cannot be erased.

Optical Memories

A variety of optical storage media using film, cards, or chips are presently available. The data stored on these are digitized and compacted.

However, similar to punched card and tape, data, once recorded, cannot be changed, i.e., they are non-rewritable read-only memories.

Core Memory

An integral part of the computer, core memory is composed of ferrite core, bi-polar, or semi-conductor (metal oxide semiconductor, usually abbreviated as MOS) memory arrays.

Figure 5 provides an overview of the above-discussed storage media.

Figure 5. Overview of Storage Media and Techniques

	STORAGE TECHNIQUE			
	Exact Copy		Digital	
STORAGE MEDIUM	Readable	Rewritable	Readable	Rewritable
Carbon Copy	X			
Duplicated Copy	X			
Printed Copy	X			
Optical Memories	X		X	
Magnetic Tape			X	X
Magnetic Drum			X	X
Magnetic Disk			X	X
Magnetic Card			X	X
Punched Card			X	
Punched Tape			X	
Core Memory			X	X

INFORMATION/RESULTS/MATERIALS TRANSMISSION

Transmission of IMS information and results to intended persons can either be accomplished manually* or in an automated mode. The same various potential means of accomplishing this feature, previously discussed in the section DATA TRANSMISSION, can be applied here.

INFORMATION/RESULTS/MATERIALS OUTPUT

This section describes the potential means by which IMS information, results, and materials can be received and generated in a form readable and understandable to the intended persons. Some of the devices that can accomplish this feature have been discussed previously in the DATA INPUT section (viz., Teletypewriter and CRT). Other devices and techniques are briefly described below.

COM

This acronym stands for Computer Output Microfilm. Information in the form of microforms is produced at the receiving end in this case. However, a microform reader is required to enable the user to read the information on the microform.

Printer

The printer is a receive only (RO) type of teletypewriter which prints the information on paper. Printers with wider carriages than teletypewriters are usually known as Line Printers.

The Computer Forms Printer (CFP) developed by Xerox Corporation transforms standard 11" x 14 7/8" computer printout into 8½" x 11" format. Also, by the use of a simple forms overlay inserted into the

*Where manual modes of transmission are employed, proper methods and procedures for coding, filing, and transmitting (e.g., mailing) the relevant information need special planning and attention.

CFP, special headings, columnar delineations, graphics, and other constant alphanumeric information can be added to each reduced copy (e.g., printing of student identification data on tests; insertion of graphics and columnar delineations in IMS reports; etc.).

Telecopier

Accepting transmission of pictures, maps, diagrams, etc., via facsimile (FAX), the telecopier at the receiving end duplicates this information on some form of paper.

Computer Synthesized Voice

Computer synthesized voice can be heard, in the simplest form, via an ordinary telephone. Such systems at the computer end are generally known as voice response systems (VRS) and can transmit computer-composed messages in spoken language (see TN 5-71-45 for a description of voice response systems).

INFORMATION/RESULTS/MATERIALS DISSEMINATION

IMS information, results, and materials can be disseminated to the intended persons either manually or in an automated mode. For manual dissemination, the information can either be distributed to the intended persons or the end users themselves can collect the information from a central location. In an automated mode, the end users receive the information on an on-line interactive basis with the input/output device, and the dissemination feature is thus eliminated.

QUERY AND INFORMATION/RESULTS/MATERIALS RETRIEVAL

Depending on the type of device and the method of operation, the query can either be on-line in an interactive mode, or in a batch mode.

Any of the data input devices discussed in the section, DATA INPUT, can be used to query an information bank. Other mechanisms for querying from a remote site are described briefly:

Facsimile Transmitter

A query or retrieval request, once written (or typed) on a sheet of paper, can be transmitted by the use of a facsimile transmitter. The request will be reconstructed and duplicated on a telecopier at the other end.

Handwriting Transmitter

This device enables the user to write something on a roll of paper attached to the transmitter, and simulatneously the same handwriting is reproduced at the other end on a similar machine via an ordinary telephone communication link.

Utilization of either of these devices necessitates a manual interpretation of the request at the computer end.

Working Paper 10

CRITERIA UNDERLYING THE FORMATION OF ALTERNATIVE IMS CONFIGURATIONS (TM 5-72-04)

Ashok Davé

TM 5-72-02 identified the operational features of a realizable Instructional Management System (IMS) configuration. Various available and potential means of accomplishing these operational features were also briefly described. It is clear that an innumerable number of IMS configurations could be formed to accomplish the operational features. In this paper, three categories are defined which may govern the formation and analysis of alternative configurations.

CATEGORY 1

Each configuration alternative will be computer-based. Automation at all possible stages of the system will be employed to minimize human intervention and manipulation of the source data and of the processing sequence.

CATEGORY 2

Each alternative configuration will employ state-of-the-art techniques and hardware; theoretical optimality will be determined at a later stage utilizing computer simulation techniques. All the configurations will be initially formed with the intent of carrying out computer-based instructional management for SWRL-developed instructional and/or learning mastery systems whose characteristics can be firmly specified.

CATEGORY 3

Three types of characteristics--school (user group) structural, test (input) structural, and report (output) structural, are described

(Fig. 1) in this category to assist delineation of the operational limits of alternative configurations. The quantitative figures in these characteristics have been assigned limits ranging from a practical lower to a predictable upper. A Modal Unit is logically derived from the limits to form a reasonable environment for alternative configurations. The alternative configurations will be formed to satisfy the Modal Unit requirements, and should have the capability and flexibility to be expanded to efficiently cover the predictable upper limits of the structural characteristics. The frequency/quantity of data/information flow in the Modal Unit are depicted in Figure 2.

Data input and information output will also occur at times other than for standard fixed inputs/outputs (as in cases of new student arrivals and transfers, late test data, special queries, etc.).

The interaction of these structural characteristics will be assessed in the context of the following constraints and/or criteria.

Cost Minimization/Benefit Maximization

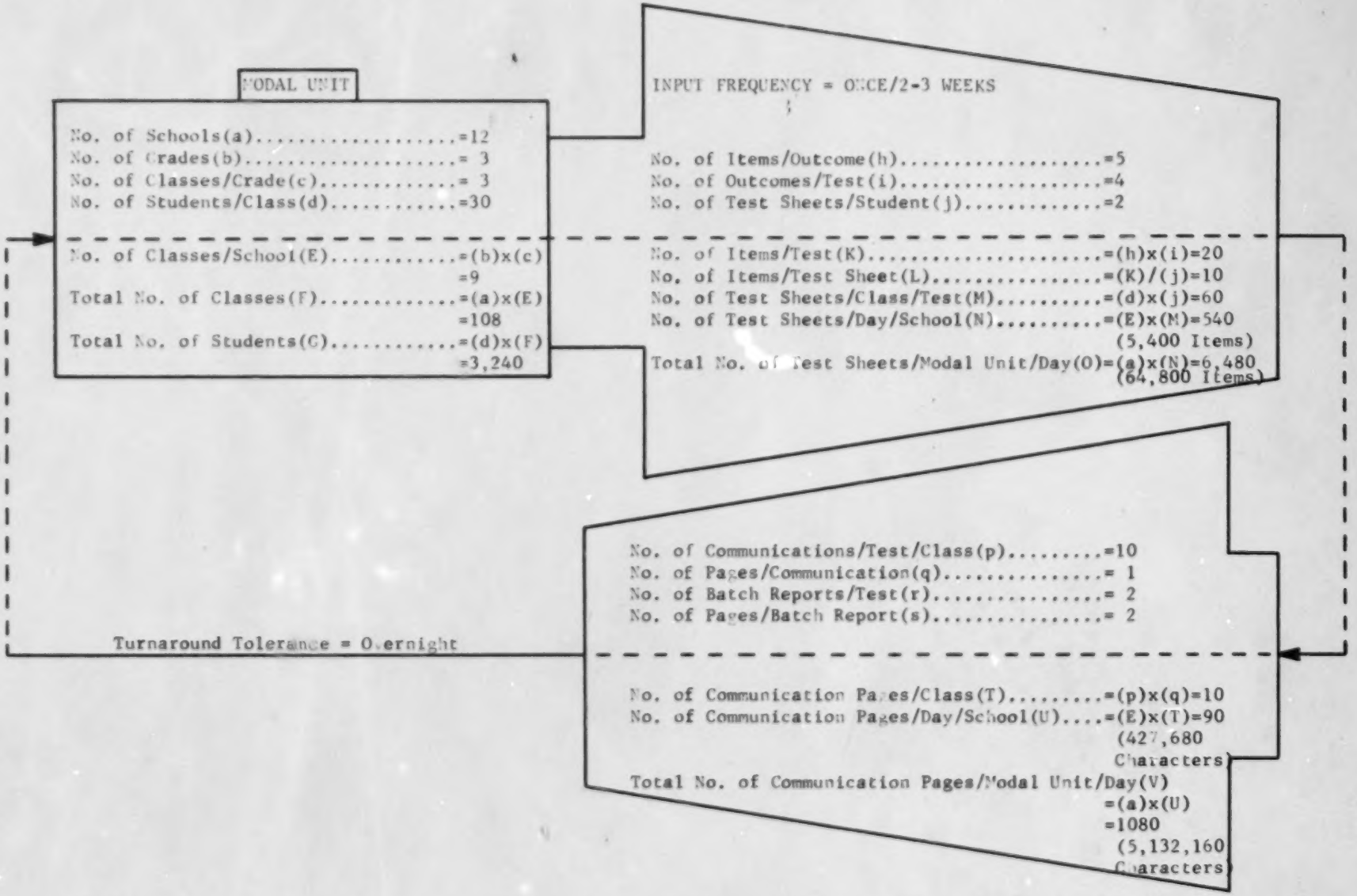
Either minimization of costs, or maximization of benefits and effectiveness of the configurations is sought. Marginal costs*, rather than average or total costs, will ordinarily be considered. Since there will be a number of alternative ways of forming one or more configurations (and later, innumerable alternative ways of improving the effectiveness

*Marginal costs are the costs of one additional unit of production, activity or service. They are the incremental (first derivative) costs of increasing the volume of business output one unit.

Fig. 1. School, Test, and Report Structural Characteristics

	CHARACTERISTICS	RANGE		MODAL UNIT
		LOWER	UPPER	
SCHOOL STRUCTURAL	Size of District	1 School	1 State	1 Local Educational Agency (LEA) of 12 Schools
	Grades	K.G.	8	1-3
	Number of Classes/Grade	1	8	3
	Number of Students/Class	10	60	30
TEST STRUCTURAL	Number of Items/Outcome	5	20	5
	Number of Outcomes/Test	1	8	4
	Number of Sheets/Student	1	4	2
	Frequency	Daily	Monthly	2-3 Weeks
REPORT STRUCTURAL	Number of Audiences/Test	1	6	4
	Length of Communication	1 Line	2 Pages	1 Page
	Number of Communications/ Test	1	50	10
	Number of Batch Reports/ Test	1	6	2
	Number of Pages/Batch Report	1	50	2
	Turnaround Tolerance	Interactive	1 Week	Overnight

Fig. 2. Frequency/Quantity of Data/Information Flow in the Modal Unit


MODAL UNIT
No. of Schools(a).....=12
No. of Grades(b).....= 3
No. of Classes/Grade(c).....= 3
No. of Students/Class(d).....=30
No. of Classes/School(E).....=(b)x(c) =9
Total No. of Classes(F).....=(a)x(E) =108
Total No. of Students(G).....=(d)x(F) =3,240
INPUT FREQUENCY = ONCE/2-3 WEEKS
No. of Items/Outcome(h).....=5
No. of Outcomes/Test(i).....=4
No. of Test Sheets/Student(j).....=2
No. of Items/Test(K).....=(h)x(i)=20
No. of Items/Test Sheet(L).....=(K)/(j)=10
No. of Test Sheets/Class/Test(M).....=(d)x(j)=60
No. of Test Sheets/Day/School(N).....=(E)x(M)=540 (5,400 Items)
Total No. of Test Sheets/Modal Unit/Day(O)=(a)x(N)=6,480 (64,800 Items)
No. of Communications/Test/Class(p).....=10
No. of Pages/Communication(q).....= 1
No. of Batch Reports/Test(r).....= 2
No. of Pages/Batch Report(s).....= 2
Turnaround Tolerance = Overnight
No. of Communication Pages/Class(T).....=(p)x(q)=10
No. of Communication Pages/Day/School(U)....=(E)x(T)=90 (427,680 Characters)
Total No. of Communication Pages/Modal Unit/Day(V) =(a)x(U) =1080 (5,132,160 Characters)

NOTE: Worst possible cases and instances are employed to minimize detailed scheduling, queuing, and probability studies at this stage of the analysis. They will, however, be carried out at later stages to minimize wastefulness of the configurational resources.

of a configuration), marginal costs will have to be estimated to select the best. Marginal ratio of benefits (increase in effectiveness) to costs for each of the alternatives will also be assessed. Effectiveness is maximized, or costs are minimized, only when the marginal ratios of benefits to costs are equal for all the competing alternative ways available for making marginal improvements in a program:

> ...if we reduce the effective payload of an aircraft by 1 in order to save $100 in the materials cost of the fuselage, then we should not simultaneously spend $200 more on the construction costs of the ailerons in order to increase payload by 1 pound. The marginal ratio of cost to benefits should be the same for all the various ways of increasing payload or of increasing any other performance characteristic....we must be sure that our dollars, or our manpower, or our facilities are used in ways that give us the greatest marginal increase in benefits. Unless we equate cost-effectiveness or cost-benefit ratios at the margin, we can be sure that we are not getting the greatest effectiveness from the resources committed to a program. No responsible decision maker can afford to be mindless of this simple and fundamental principle (Fisher, 1971).

Economic Worthwhileness

The service must have a utility to the users that equals or exceeds the sum of the proper costs of making it available to them.

Financial Feasibility

The utilization of the configuration must be financially supportable.

Physical Realizability and Availability

The components of the configuration must be physically available or in specifiable prototype form.

Reliability

This feature concerns the reliability and performance of the configuration over time. The configuration should be reliable with high Mean-Time-Between-Failure (MTBF).

Operability, Maintainability, and Serviceability

The configuration should be easy to operate and maintain, requiring minimal user training. Aesthetics and environmental requirements should be considered for components to be stationed at school sites. Service and repairs must be both on a periodic basis and on-demand, and alternatives for carrying out IMS functions should be available in cases of component malfunction and/or breakdown.

Flexibility, Adaptability, and Expandability

The configuration should be flexible to accommodate reasonably alternative components to meet the needs of the moment and have the capability of expansion to meet new requirements. Rigidity of design should be minimized. Exceptions to conform with existing industrial standards will be explicitly noted.

Security

The configuration should have the capability to reject access and utilization by unauthorized users. This is an essential consideration to protect individual and institutional privacy.

REFERENCE

Fisher, Gene H., Cost Considerations in Systems Analysis, New York: American Elsevier Publishing Company, 1971.

Working Paper 11

TOTAL SYTEMS CONSIDERATIONS IN FORMING ALTERNATIVE CONFIGURATIONS FOR A COMPUTER-BASED INSTRUCTIONAL MANAGEMENT SYSTEM (TN 5-72-13)

Ashok Davé

SWRL's Instructional Management System (IMS) is designed to collect individual performance data from schools, to process the data, and to provide useful derivative information to persons responsible for some aspect of the pupil's performance. IMS operational features and the alternative means of accomplishing these features are briefly identified in TM 5-72-02. Criteria, classified in three categories, were developed in TM 5-72-04 to provide a framework for the formation of alternative configurations. In addition to these a number of other considerations of a comprehensive system need to be clarified and understood. These considerations are briefly discussed in the following sections of this paper.

Data Communications

A lion's share of the capabilities and costs of most IMS configurations will be borne by the data communications network of the system. The system network must be able to satisfy user requirements in a cost-beneficial manner. Martin (1970), while discussing means of lowering communication network costs, points out that:

> If the lines are very long, they are expensive, so techniques for minimizing the cost of the lines needed dominate the network design. If the lines are short, their cost is of less concern, and the cost of the terminals and devices attached to the lines is of greater importance. Where the lines are very short, for example, all in one plant, one office block, or one campus, then their cost is of little significance in the design, and we often find their bandwidth being used quite wantonly. If a system has a large number of terminals, then the terminal cost becomes of major importance and the network organization should use schemes

> that enable the terminal design to be as inexpensive as possible... If the lines are more than 100 miles or so long, the line cost dominates the network design.

Naturally, a product (configuration) has to be ready, marketable, and attractive to the customer (user) before he can buy it. This problem can be solved by forming preliminary flexible configurations, determining their initial basic costs and capabilities, and then modifying a basic configuration as necessary to yield a maximally cost-effective system for each given user. Another approach could be to build a fairly large number of hypothetical user environments and form configurations to suit those environments. As before, when a special real-life user environment is identified, the configuration(s) most closely fulfilling the user requirements can be selected, modified, and presented as a package.

Loading/Distribution of Data Processing Operations

The next consideration is somewhat dependent on the previous one. An analysis should be inclusive of alternative ways of loading/distributing various data processing operations of a computer-based IMS. This can be exemplified by illustrating the SWRL IMS experimental configuration. It may pay off to carry out, for example, scoring and reporting at the PDP 8/I, leaving diagnosis, prescription and generation of instructional materials to the main computer.

A corollary stems from the fact that it may be desirable and cost-effective to have the scoring done by teachers at schools only (thereby eliminating unique input hardware, methods, and procedures), and the later functions, viz, reporting, diagnosis, prescription and generation

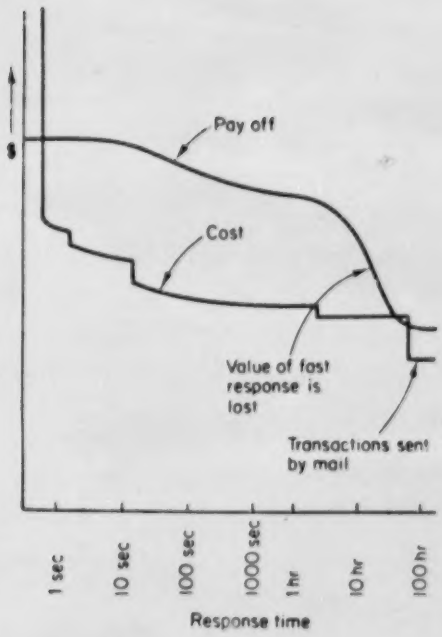
of instructional materials to be carried out by the computer. A potential user may want to utilize only Functions 1 and 2, and is therefore interested in a configuration only for these functions. Thus, there is an analytic requirement for configurations that can carry out any combinations of Function 1 with one, two, or all three of Functions 2, 3, 4.

Response Time

The third consideration concerns the need to determine cost of different response (turnaround) times, and their relative values to the potential users. A single configuration can be represented in terms of a range of costs and benefits on the basis of different turnaround time requirements. Response time requirements and their value for different IMS functions, reports, etc., must be known to form alternative configurations. Martin (1967) illustrates by the use of a simple cost-response time graph (see Fig. 1) how the cost of systems giving different response times may vary. The graph also depicts the variation of system value with the response time. In some applications, the value of having a fast, or real-time, response is considerably greater than that of a slow response. In other applications the payoff curve would be flatter, less dependent on response time. Martin (1967) further discusses a range of commonly found response-time requirements:

- Immediate (< 1 second)
- Conversational (< 15 seconds)
- As soon as it is convenient (within minutes)
- Deferred, on-line (< 1 hour)
- Within one day
- Long time available (weekly; mail mode)

Fig. 1. Cost-Response Time Relation



Note: The various functions carried out by one system often need different response times. These curves are likely, therefore, to be an oversimplification. Also, they are based on having a single, large computer doing data processing for commercial usage.

Various IMS outputs and queries may have response-time requirements at different places on such a range. From the system configuration perspective, a short response time may be as easy or, what is more important, as inexpensive to achieve as a longer one; sometimes not. Peak values of data traffic and their timings also play an important role for configuration formation.

Computer Software

The next consideration is related to the software aspects of the computer-based IMS configurations. It can be safely assumed that all of IMS applications programs, which have been written in Fortran, can be used on almost any machine with minor modifications. However, all the machine language programming carried out on SWRL's Data Concentrator, a Digital Equipment Corporation (DEC) PDP 8/I, will necessitate a major reprogramming effort by the potential users for their machine, if it is other than a DEC PDP 8/I. This would result in an increase in the total cost of such a configuration, which should be treated in comparing costs and effectiveness of alternative configurations.

Flexibility

The fifth consideration regards the flexibility and modularity of the configurations. As indicated in TM 5-72-02, computer costs may be expected to descend, while our ability to use them effectively may be expected to rise. What will be the implication of this trend on common school users? Even those users who are presently not much interested in IMS now may tend to be more attracted in the near future. Thus, the configurations formed at this stage, and in the future, must be sufficiently

flexible to accommodate and integrate future low-cost equipment. They should also have the capability to be expanded to carry out programs other than IMS, such as business and other student record applications. The need for a flexible configuration is evident from Cooley's (1970) conclusions with Individually Prescribed Instruction (IPI) at the Learning Research and Development Center (LRDC) at the University of Pittsburgh:

(1) The teacher and teacher aides in an IPI system can and will use computer assistance in recordkeeping and student monitoring function.

(2) The data-entry devices and student files must be much more flexible than the system of scan forms and fixed-format records which had been implemented. One objective of the IPI approach is a flexible system, but the lead time involved in printing scanner forms and in computer programming tended to produce inflexibility of operation.

(3) The data-retrieval system needs to be more accessible to the teacher. The demands for reports at the school became so great that we had to add a teletype to assist in report generation. This allowed data entry and report generation to go on simultaneously, but even this was not ultimately what the teachers wanted. We tried one teletype at a resource center next to a classroom, but it was rejected because it was too slow, too noisy, and too cumbersome for teacher use. The need in the classroom is for quiet devices which will allow the teacher to interact quickly and easily with the information required at the time a child is at her side, to review his record, and to plan future studies for him.

REFERENCES

Cooley, William W., "Computer Assistance for Individualized Education," Journal of Educational Data Processing, 7(1), 1970, p.21.

Martin, James, Design of Real-Time Computer Systems, Englewood Cliffs: Prentice-Hall, 1967, pp. 42-44.

Martin, James, Teleprocessing Network Organization, Englewood Cliffs: Prentice-Hall, 1970, pages 118, 127.

Working Paper 12

THE USE OF SIMULATION IN THE DESIGN OF A COMPUTER-BASED INSTRUCTIONAL MANAGEMENT SYSTEM (TN 5-72-12)

Burton J. Roffman

The SWRL Instructional Management System (IMS) utilizes a configuration of Electronic Data Processing (EDP) equipment to transform instructional program performance data into instructional program management information and a set of materials and operating procedures which determine how and in what form the data are collected and the information reported. Program performance data include measurements of the performance of pupils as they participate in one or more well defined instructional programs. IMS stores descriptive information about the instructional programs and their participants. The performance data are analyzed, summarized, and combined with this descriptive information to yield instructional program management information. This information is relevant to the requirements of the teachers, parents, principals, district administrators and pupils.

The range of equipment available for IMS includes small, medium and large scale digital computers (central processing units), core memories, disk and drum storage units, magnetic tape drives, paper tape and punched card readers and punches, keyboard input devices, magnetic and optical mark sense readers, character printers, line printers, graphical and optical output devices, telecommunications lines and assorted black box interfaces and connectors. SWRL has initially selected from this range of equipment a configuration consisting of desk top optical mark readers readers, low speed keyboard character printers, and a small scale digital computer with sufficient disk and tape peripherals to function as a data concentrator. The concentrator transmits and receives data over telecommunications lines which connect with the readers and printers, and

concentrator. The concentrator transmits and receives data over telecommunications lines which connect with the readers and printers, and with a large scale, multiprogrammed computer system that maintains and executes the main library of IMS processing programs. If the data concentrator unit has the features necessary for multiplexing, then its communications control program may be written to allow simultaneous communications from many readers and/or printers. Otherwise, transactions with each device must be handled separately and sequentially.

One objective of this study was to explore the relative effect of the sequential and the overlapped program logic on the operation of the proposed IMS configuration. However, the operation of the system is equally affected by the timing pattern of the separate processes which the system performs. The basic dichotomy is fixed phasing versus variable phasing. Processes may be constrained to fixed mutually exclusive time intervals within a daily cycle; or, they may occur on-demand, throughout the day, constrained only by equipment availability. Combining these two types of timing patterns with the two alternative program logics yields four IMS-EDP operating models, Fixed Phase Sequential (FPS), Variable Phase Sequential (VPS), Fixed Phase Overlapped (FPO), and Variable Phase Overlapped (VPO). This study investigates the impact on system performance of each of these models in terms of relative device utilization rates, system thruput time, and system thruput capacity.

Performance parameters were estimated using IBM's General Purpose Simulation System (GPSS) program language. The VPS model was defined by a block diagram flowchart according to standard GPSS block types. The diagram was translated into a sequence of GPSS statements, which, when executed under control of the GPSS simulation algorithm, simulate

the activity of IMS with VPS constraints. Various additional statement sequences were merged with the VPS coding to create programs which would simulate the other three models.

The basic VPS system model consists of a variable number of optical scanner input devices and character printer output devices located at participating school sites, a small digital computer data concentrator unit (DCU) placed in a district location, a large scale central processing computer (CPU) in a regional service center, and a two way transmission line (CPLN) between DCU and CPU. All of the scanners have the same operating characteristics as do all of the character printers. It is assumed that the input and output devices will be linked to the DCU by dial-up telecommunications lines, but these lines are not explicitly included in the model because their utilization is identical to the aggregate I/O device utilization.

Transactions which flow through the system undergo a sequence of five processes. The first process is the Input process. One scanner is linked to the DCU. The input data are interpreted from the scan forms, sent to the DCU, coded or concentrated and written onto a magnetic tape file. In the second process the coded contents of this tape are transmitted to a random access disk storage unit which holds the job stream for the central processor. The DCU is linked to the CPU via the telecommunications line (CPLN). This process is labeled the Transmission process. The third process is the Central Computer process. The class test data are merged with data from the instructional program data base and other appropriate sources. Comparisons and analyses are performed

according to programmed algorithms. The resulting information is shaped into a coded file of output report page images which enters the output job queue. In the fourth process this output file is transmitted to the DCU and written onto magnetic tape. The CPU is linked to the DCU via the same telecommunications line used in Process Two. Process Four is called the Receiving process, from the viewpoint of the DCU. The fifth process is Output. The DCU is linked to the character printer at the transaction's originating site. The report page images from the output tape file are decoded, transmitted to the output device and printed as hard copy.

The detail level of the coded model does not include such things as tape usage, disk storage and storage of paper forms, because of the focus on thruput statistics and equipment utilization. Processes are represented by the amount of equipment time required to handle one transaction. These times are coded in five functions, ITIME, TTIME, CTIME, RTIME, and OTIME. One clock unit is defined as one tenth (.1) minute. Transactions begin as the data from one class on one unit of one instructional program enter the model. The entry rate is specified by the GENERATE statement. The listing in Figure 1 shows a GENERATE statement that causes an average interval between transactions of 80 minutes, varying between 40 minutes and 120 minutes. By changing this statement the analyst can simulate different load patterns corresponding to a variety of operating environments.

A transaction enters the model by entering a scanner queue randomly determined by the input device number (IDNUM) function. Changing this

function changes the number of devices in the model and/or the relative number of transactions per device. In the listing IDNUM is set to distribute transactions evenly among twenty scanners. The transaction departs the scanner queue after seizing the appropriate scanner when it becomes available. It then enters the data concentrator input queue (DCIQ), seizes the data concentrator when available, and departs the DCIQ. The scanner and the data concentrator are held for a number of clock units randomly determined by the input time (ITIME) function. In Figure 1 ITIME specifies an average input time of 12 minutes with a range of 8 to 16 minutes. Changing this function changes the simulated speed capabilities of the scanners or the average size of a transaction. This is because transaction size is a derivative of class size and instructional program size. After ITIME has elapsed the scanner and the data concentrator are released and the transaction is buffered. This means it does not proceed directly to the next process and seize the DCU which it has just released. Instead it goes to the end of the queue for that device, allowing transactions which have been generated or advanced during the ITIME interval to compete equally for DCU services.

The Transmission, Receiving and Output processes are coded in a similar manner. Queue statistics are kept for each piece of equipment, aggregately and by process. For example, the DCQ keeps tract of all entries to the data concentrator while the DCOQ monitors only that subset of entries which are seeking Output processing. Equipment is seized according to the priorities of the VPS logic and released after an elapsed time specified by the appropriate function. The Central Computer

process is a partial exception to this pattern. The central processor (CPU) is represented by a storage room entity instead of a unit capacity facility. This allows for the multiprogramming.

As a transaction terminates it is counted and entered into a frequency distribution table according to its thruput time. This table is printed as part of the output statistics for each simulation run. An artificial GENERATE-TERMINATE sequence appears after the TERMINATE statement for the basic model. It acts as a clock and permits the simulation to be run for a specified amount of time rather than a specific number of transactions.

The VPS model was converted into the FPS model by the addition of a time period marking sequence and by the insertion of TEST blocks which prevent transactions from undergoing a process until the time period marker (SAVEVALUE X1) is set for that process. K1 is the code for Input periods, K2 for Output periods, and K3 for Transmission and Receiving. Central Computer processing does not require the services of the DCU and is therefore independent of these time interval restrictions.

The VPO model is also derived directly from the VPS model. A set of computed VARIABLE statements divides the ITIME and OTIME function values into two parts on the basis of the overlap ratio desired. One part applies to the DCU. The other part applies to the input or output device. ADVANCE statements are changed and/or inserted accordingly. The Transmission and Receiving processes are not overlapped because there is only one line between DCU and CPU. Given these FPS and VPO modification provisions it is simply a matter of adding them together to yield the final FPO model, shown in Figure 1.

Figure 1
Card Listing of Fixed Phase Overlapped (FPO) Model

```
      SIMULATE
IPDEV FCV         2(20),C,F
OPDEV F.J         22(20),C,F
MAIN  STORAGE     5
*                                 INPUT DEVICE NUMBER
 IDNUM FUNCTION   RN1,C2
0.0,0/1.0,20
*                                 OUTPUT DEVICE NUMBER
 ODNUM FUNCTIO    RN2,C2
0.0,0/1.0,20
*                                 TIME FOR INPUT PROCESS
 ITIME FUNCTION   RN3,C2
0.0,80/1.0,160
*                                 TIME FOR TRANSMISSION PROCESS
 TTIME FUNCTION   RN4,C2
0.0,3/1.0,13
*                                 TIME FOR CENTRAL COMPUTER PROCESS
 CTIME FUNCTION   RN5,C2
0.0,20/1.0,80
*                                 TIME FOR RECEIVING PROCESS
 RTIME FUNCTION   RN6,C2
0.0,10/1.0,20
*                                 TIME FOR OUTPUT PROCESS
 OTIME FUNCTION   RN6,C2
0.0,140/1.0,260
*                                 10% OVERLAP DATA CONCENTRATOR TO INPUT DEVICE
     1 VARIABLE   P3/K10
     2 VARIABLE   K9*P3/K10
*                                 10% OVERLAP DATA CONCENTRATOR TO OUTPUT DEVICE
     3 VARIABLE   P11/K10
     4 VARIABLE   K9*P11/K10
*                                 RATE OF INCOMING TRANSACTIONS
       GENERATE   80,40
*                                 ENTER MODEL
       ASSIGN     1,IPDEV
       ASSIGN     1+,FN$IDNUM
       ASSIGN     2,OPDEV
       ASSIGN     2+,FN$ODNUM
       ASSIGN     3,FN$ITIME
       ASSIGN     5,FN$TTIME
       ASSIGN     7,FN$CTIME
       ASSIGN     9,FN$RTIME
       ASSIGN     11,FN$OTIME
*                                 ENTER INPUT DEVICE QUEUE
       QUEUE      P1
       SEIZE      P1
       DEPART     P1
       QUEUE      DCIC
       QUEUE      DCC
*                                 WAIT UNTIL INPUT TIME PERIOD
       TEST E     X1,V1
       SEIZE      DCV
       DEPART     DCIC
       DEPART     DCC
*                                 INPUT PROCESS
       ADVANCE    V1
       RELEASE    DCV
       ADVANCE    V2
```

```
          RELEASE   P1
          QUEUE     TLNO
*                             ENTER TRANSMISSION LINE QUEUE
          QUEUE     TLNO
          BUFFER
          SEIZE     CPLN
          DEPART    LNO
          DEPART    TLNO
          QUEUE     DCTO
          QUEUE     DCO
*                             WAIT UNTIL TRANSMISSION TIME PERIOD
          TEST E    X1,X3
          SEIZE     DCU
          DEPART    DCTO
          DEPART    DCO
*                             TRANSMISSION PROCESS
          ADVANCE   P5
          RELEASE   DCU
          RELEASE   CPLN
          QUEUE     MAINQ
          ENTER     MAIN
          DEPART    MAINQ
*                             CENTRAL PROCESSING
          ADVANCE   P7
          LEAVE     MAIN
          QUEUE     LNO
*                             ENTER RECEIVING LINE QUEUE
          QUEUE     RLNO
          BUFFER
          SEIZE     CPLN
          DEPART    RLNO
          DEPART    LNO
          QUEUE     DCRO
          QUEUE     DCO
*                             WAIT UNTIL RECEIVING TIME PERIOD
          TEST E    X1,X3
          SEIZE     DCU
          DEPART    DCRO
          DEPART    DCO
*                             RECEIVING PROCESS
          ADVANCE   P6
          RELEASE   DCU
          RELEASE   CPLN
*                             ENTER OUTPUT DEVICE QUEUE
          QUEUE     P2
          BUFFER
          SEIZE     P2
          DEPART    P2
          QUEUE     DCOO
          QUEUE     DCO
*                             WAIT UNTIL OUTPUT TIME PERIOD
          TEST E    X1,X2
          SEIZE     DCU
          DEPART    DCOO
          DEPART    DCO
*                             OUTPUT PROCESS
          ADVANCE   P8
          RELEASE   DCU
```

```
          ADVANCE     V4
          RELEASE     F2
          TABULATE    TABU
          TERMINATE
          GENERATE    4800,,,1
          SAVEVALUE   1,X3
*                                  6:30 - 8:15  TRANSMISSION AND RECEIVING
          ADVANCE     X150
          SAVEVALUE   1,X2
*                                  8:15 - 9:30  INPUT
          ADVANCE     X720
          SAVEVALUE   1,X1
*                                  9:30 - 11:15 OUTPUT
          ADVANCE     X1050
          SAVEVALUE   1,X3
*                                  11:15 - 12:00 TRANSMISSION AND RECEIVING
          ADVANCE     X450
          SAVEVALUE   1,X1
*                                  12:00 - 12:45 INPUT
          ADVANCE     X450
          SAVEVALUE   1,X3
*                                  12:45 - 1:30  TRANSMISSION AND RECEIVING
          ADVANCE     X450
          SAVEVALUE   1,X2
*                                  1:30 - 3:30  OUTPUT
          ADVANCE     X1200
          SAVEVALUE   1,X3
*                                  3:30 - 4:00 TRANSMISSION AND RECEIVING
          ADVANCE     X300
          TERMINATE
*                                  LENGTH OF SIMULATION TIME KEEPING
          GENERATE    600
          TERMINATE   1
TABU      TABLE       M1,0,150,100
          START       1
          END
```

In order to run the simulation programs a number of values and initial conditions must be specified. The number of input and output devices and the values of the five process time functions are common to all four models. Twenty (20) I/O devices prevent bottle necks at particular school sites while allowing a sufficient load to tax the overall processing capacity of the system. Scanner speed is set at five (5) pages per minute. Input transactions average sixty (60) pages (thirty (30) pupils per class, two (2) pages per test). The resulting ITIME function specifies an input process time of twelve (12) minutes plus or minus four (± 4), corresponding to a variance of plus or minus twenty (± 20) pages. Similarly, the character printer speed is set at ten (10) characters per second and output transactions average twelve thousand (12,000) characters (five (5) pages at forty (40) lines per page at sixty (60) characters per line). This yields an Output process time (OTIME) of twenty (20) minutes plus or minus six (± 6), a variance of plus or minus one and one-half (± 1½) pages.

Transmission between DCU and CPU occurs at a rate of two thousand (2,000) bits per second. At eleven (11) bits per character, this is approximately one hundred eighty (180) characters per second. The TTIME function specifies one (1) minute plus or minus one-half (± ½) per transaction, which is derived from sixty (60) pages at one hundred eighty (180) characters per page by one hundred eighty (180) characters per second. A one-half (½) minute variance corresponds to a thirty (30) page variance. This is larger than the twenty (20) page variance implied by ITIME because TTIME is also influenced by start, stop and line failure factors. These

same factors also influence the Receiving process. Thus, RTIME is set at one and one-half (1½) minutes plus or minus one-half (± ½), slightly larger than the sixty seven (67) seconds derived from twelve thousand (12,000) characters by one hundred eighty (180) characters per second. Finally, the CTIME function is set at five (5) minutes plus or minus three (± 3). This figure will be revised when further studies focus on the Central Computer configuration. However, because of the over-riding prominence of the DCU in the present context, the five (5) minute Central Computer processing time acts merely as an additive delay in the thruput time without otherwise affecting system functioning.

Two other initial conditions must be mentioned in addition to these common value specifications. First, in the FPO and VPO models the overlap ratio between DCU and input or output devices is ten percent (10%). For example, if an output process required twenty (20) minutes of printer time it would require two (2) minutes of DCU spread over the twenty (20) minute interval. At this ratio up to ten devices could be handled simultaneously. The second condition relates to the fixed phase models, FPS and FPO. In these models the time period schedule divides an eight (8) hour day as shown in Table 1. The constraints are such that a process may only begin during an interval appropriate to it, although it may run into the interval immediately following.

Each of the models was run under increasing load conditions until the overload point was found. A total of sixteen runs were made. The pertinent statistics from these runs are summarized in Table 2. For comparison purposes, Table 3 selects the statistics which correspond to peak load functioning for each model.

Table 1

Fixed Phasing Schedule

PERIODS DURING WHICH TRANSACTIONS MAY BEGIN A SPECIFIED PROCESS	
8:00 - 8:15	Transmission/Receiving
8:15 - 9:30	Input
9:30 - 11:15	Output
11:15 - 12:00	Transmission/Receiving
12:00 - 12:45	Input
12:45 - 1:30	Transmission/Receiving
1:30 - 3:30	Output
3:30 - 4:00	Transmission/Receiving

The data show that with the given function values under the given conditions the VPS model may be expected to dependably process up to fourteen (14) transactions per day with an average thruput time of approximately two hours. Thruput time is measured from point of entry to the model, which means that delays in seizing an input device are included. Note that in the VPS model thruput time can be reduced to one and two tenths (1.2) hours at a cost of one transaction per day. Conversely, attempting to enter fifteen (15) transactions per day into the system results in huge queue buildups and inflated thruput time with minimal gain in daily thruput. Also, under the overload condition the demand for the CPLN rapidly becomes the primary congestion point.

There is a similar pattern to the data for the FPS model, but on a different scale. At a peak load of fourteen (14) transactions per day

Table 2

Results of Simulation Runs for Four Models

Input Load In Trans./ Day	Percent DCU Util.	Average Wait For CPLN - Minutes	Max. Length Of DCQ	Max. Length Of INQ	Total Thruput	Thruput Per Day	Average Thruput Time - Minutes	Standard Deviation
Variable Phase Sequential (VPS) - 60 Days								
12 ± 6	84.7	0.0	3	2	720	12.0	55	21.0
13 ± 6½	91.0	0.0	4	3	775	12.9	69	30.3
14 ± 7	97.7	0.0	7	6	833	13.9	122	65.4
15 ± 7½	100.0	883.7	38	73	832	13.9	3680	568.0
Fixed Phase Sequential (FPS) - 60 Days								
12 ± 6	84.1	25.8	17	14	713	11.9	469	109.5
13 ± 6½	90.9	99.3	22	24	775	12.9	752	161.8
14 ± 7	97.9	199.9	21	26	835	13.9	984	128.9
15 ± 7½	100.0	645.5	38	91	832	13.9	4359	574.4
Fixed Phase Overlapped (FPO) - 60 Days								
32 ± 16	35.1	47.5	23	28	1900	31.6	344	122.3
48 ± 24	53.2	76.1	29	46	2873	47.9	375	91.6
56 ± 28	62.6	103.2	34	63	3390	56.5	428	92.6
60 ± 30	65.5	276.0	31	132	1763	58.8	759	109.9 *
Variable Phase Overlapped (VPO) - 60 Days								
68 ± 34	76.0	0.0	5	3	4122	68.7	45	7.7
80 ± 40	89.2	0.1	6	5	4833	80.5	49	8.9
87 ± 44	97.0	18.7	9	9	5263	87.7	59	13.0
96 ± 48	100.0	308.9	38	166	1864	74.5	1281	201.5 *

* 30 days

* 25 days

Table 3

Selected Statistics for Each Model

Model	Thruput* Per Day	Percent DCU Util.	Wait For CPLN - Minutes	Max. Length DCQ	Max. Length LNQ	Average Thruput Time Minutes	Standard Deviation
VPS	13.9	97.7	0.0	7	6	122	65.4
FPS	13.9	97.9	144.4	21	26	984	128.9
FPO	56.5	62.6	103.2	34	63	428	92.6
VPO	87.7	97.0	18.7	9	9	59	13.0

* Unit of thruput equals number of transactions.

the average thruput time is slightly greater than two days with a DCU utilization of ninety seven percent (97%). It requires a reduction of two transactions per day in thruput to reduce the thruput time below one day. One day thruput means overnight turnaround for individual transactions. The contrast between two hour and overnight turnaround is the major difference between the VPS and FPS models. It is also notable that, with the FPS model, even under the lighter load conditions, there is considerable delay in obtaining the CPLN to perform the Transmission and Receiving processes. This is due to the fixed phasing which automatically introduces a certain amount of delay and waste.

A sharp contrast in average thruput time also exists between the two overlapped models. At fifty six (56) transactions per day the FPO model exhibits a thruput time of approximately seven (7) hours. This corresponds to a DCU utilization of only sixty two percent (62%).

However, the size of the queue for CPLN and the associated delay time indicate that this level is just below overload. This is confirmed by the statistics for an input load of sixty (60) transactions per day. The model only processes fifty nine (59) transactions and there is rapid escalation in queue buildups and time delays. In the case of the VPO model the average thruput time is less than one hour at eighty (80) transactions per day and eighty nine percent (89%) DCU utilization. This is more thruput in considerably less time than the FPO model. Also the average waiting time for CPLN is negligible as with the VPS model.

It is possible that an adjustment of the timing schedule shown in Table 1 would improve the performance of the fixed phase models. However, initial attempts to follow this suggestion have been unsuccessful. As the data indicates, it appears that overlapping or multiplexing of input and output devices is critical to the transactional capacity of a computer-based IMS, with the increase over sequential models being at least a factor of five. At the same time, any turnaround time significantly less than overnight seems to depend on the elimination of fixed phasing or mutually exclusive time periods for separate processes in the IMS operating procedures. The size parameters of each installation impose different performance requirements on the proposed system. IMS designers may plan accordingly.

This study is valuable for the planning and design information it has evolved, and because it demonstrates how systems simulation may be used to determine the best operating procedures for a given assembly of

equipment in a given environment. It provides an operational model for a computer-based instructional management system and shows how this model may be coded for simulation purposes. It relates the coding to the aspects of the real system which are represented and shows how necessary function values may be derived. The type of statistical results which a simulation yields are exhibited and discussed in context. The completed models maintain an on-going facility for the evaluation of newly developed technology relevant to the modeled system. For example, the impact of a faster input scanner could be easily studied by changing the values of the ITIME function. Useful information might also be obtained by expanding the present models and increasing their level of detail.

APPENDIX

FLOWCHART LAYOUT FORM

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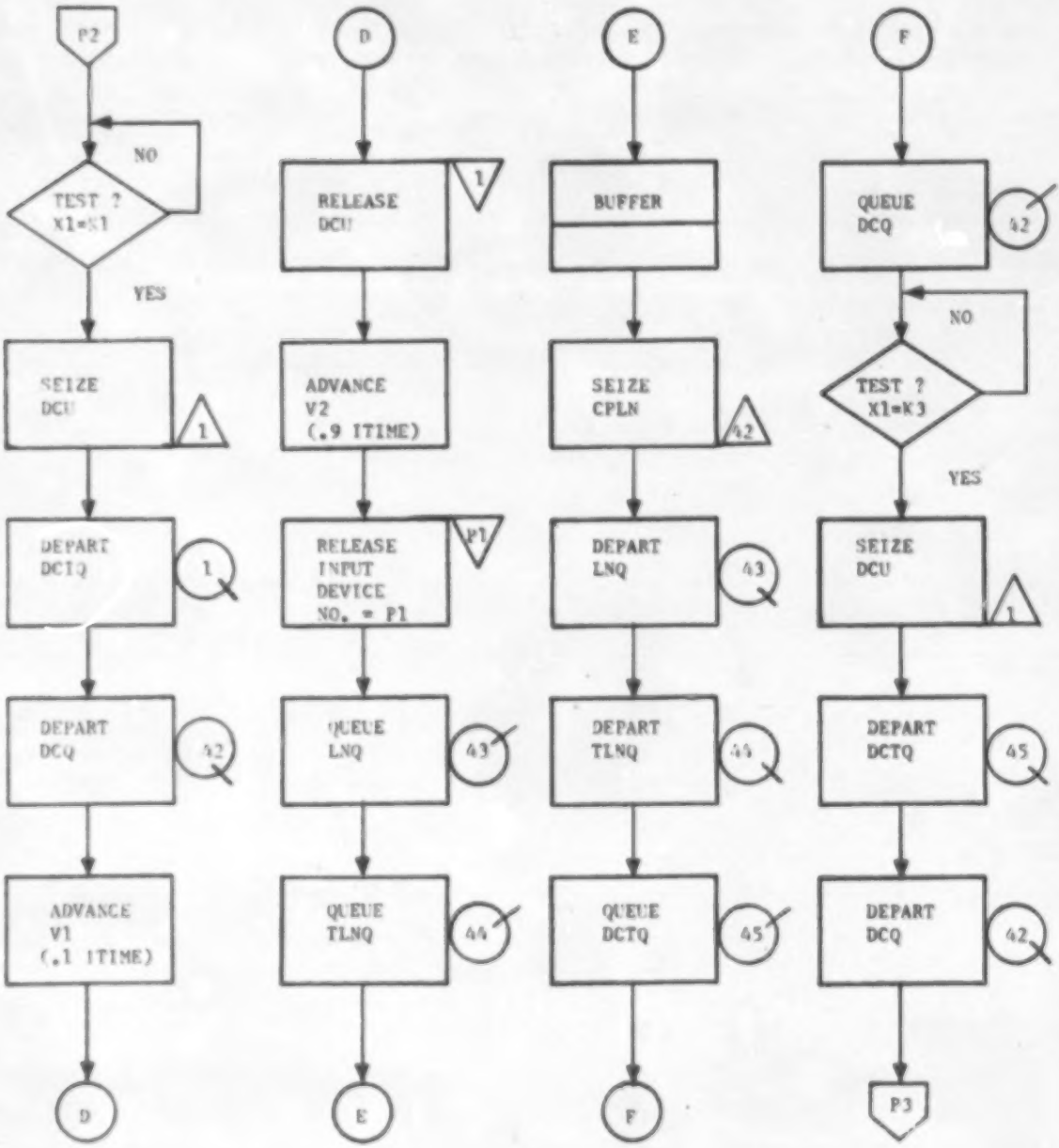
PROGRAM ID: _____ PAGE ___

FLOWCHART LAYOUT FORM

PROGRAMMER: _____ DATE: ___
PROGRAM ID: _____ PAGE ___



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FLOWCHART LAYOUT FORM

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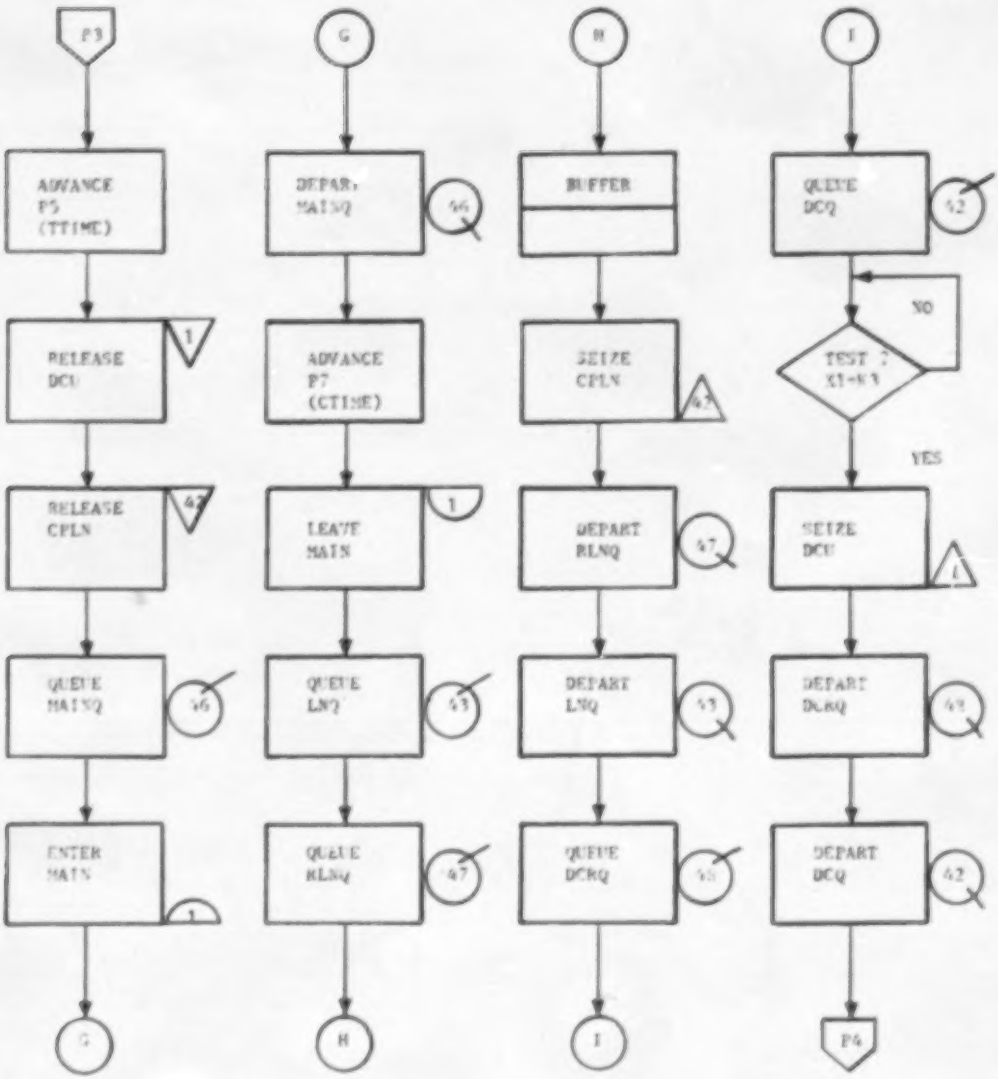

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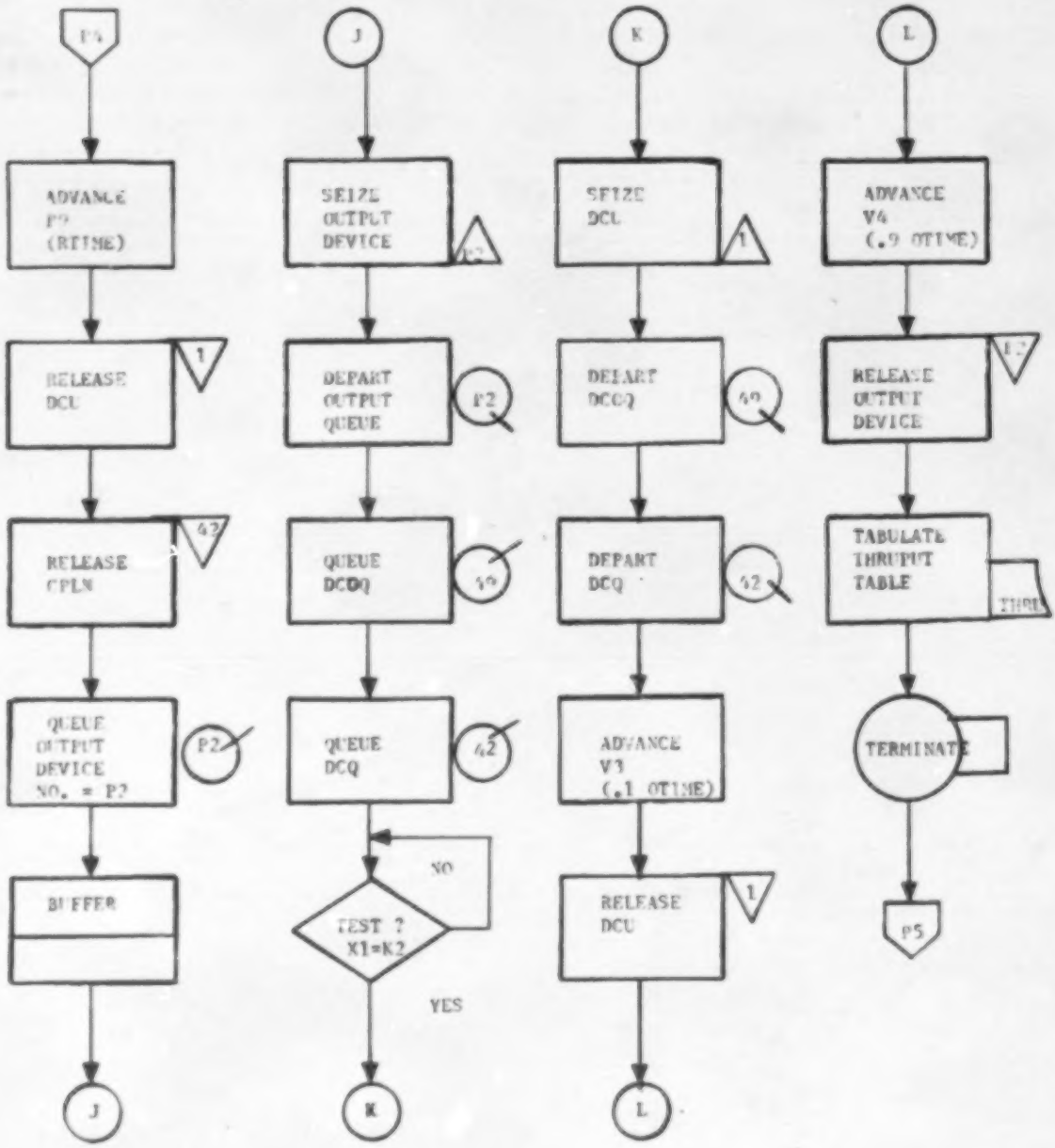

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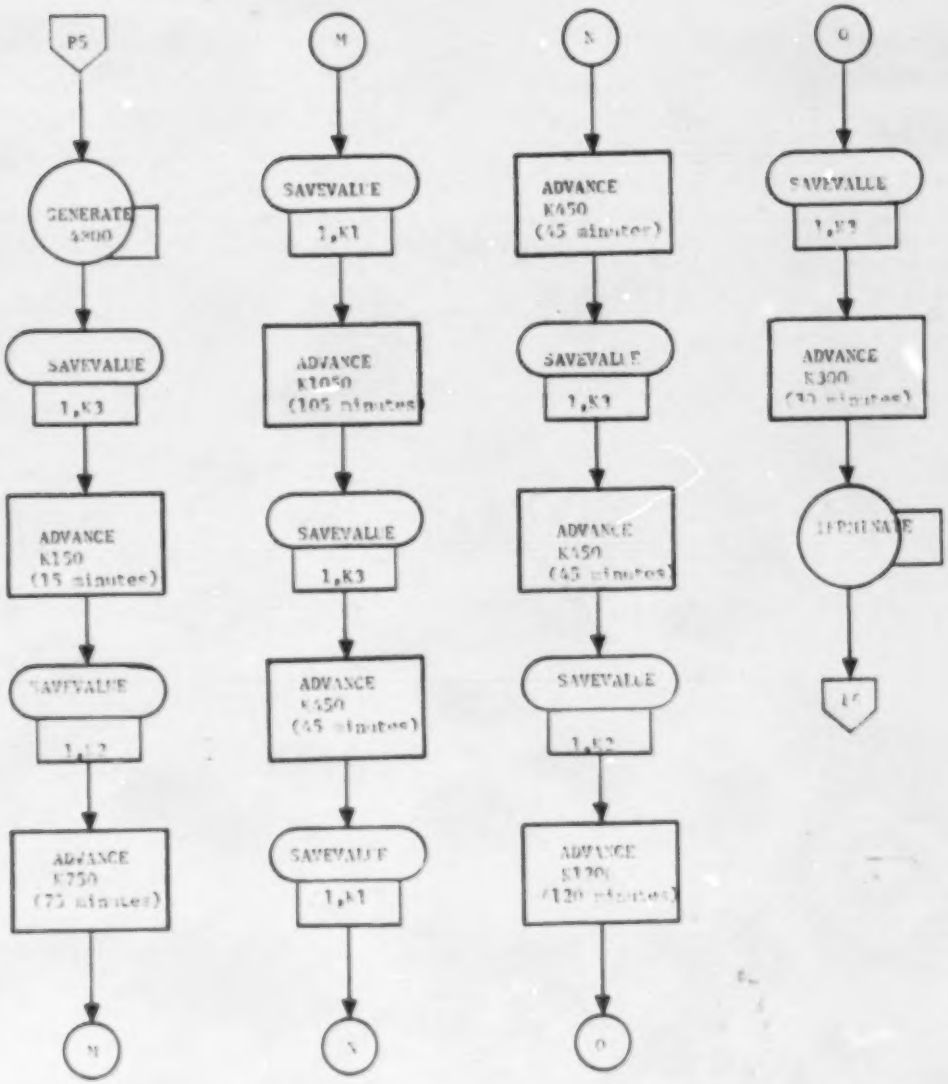

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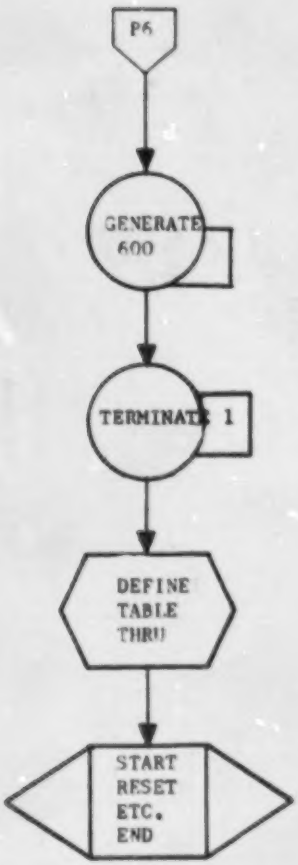
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